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FOR THE

## FIRST SESSION OF THE FORTY-SEVENTH CONGRESS,

1881-'82.

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# REPORT OF THE SUPERINTENDENT

OF THE

# U. S. COAST AND GEODETIC SURVEY

SHOWING

## THE PROGRESS OF THE WORK

DURING THE

FISCAL YEAR ENDING WITH

JUNE, 1881.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1883.

# LETTER

FROM THE

# SECRETARY OF THE TREASURY,

TRANSMITTING,

*In compliance with section* 4690 *of the Revised Statutes, a report of the Superintendent of the Coast and Geodetic Survey, showing the progress made in that survey during the fiscal year ending June* 30, 1881.

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JANUARY 16, 1882.—Referred to the Committee on Commerce and ordered to be printed.

TREASURY DEPARTMENT, *January* 11, 1882.

SIR: In accordance with section 4690 of the Revised Statutes, I have the honor to transmit herewith, for the information of the Senate, a report addressed to this Department by J. E. Hilgard, Superintendent of the Coast and Geodetic Survey, showing the progress made in that survey during the fiscal year ending June 30, 1881.

Very respectfully,

CHAS. J. FOLGER,
*Secretary.*

The Honorable DAVID DAVIS,
*President pro tempore, United States Senate.*

# ABSTRACT OF CONTENTS OF REPORT.

PART I.—Transmitting report, allusion to death of late Superintendent, C. P. Patterson, LLD. Introductory remarks on progress of work of the Coast and Geodetic Survey of the United States, pp. 1, 2. Progress of magnetic survey of whole country, p. 1. Investigations in Gulf Stream, Gulf of Mexico, and Caribbean Sea, pp. 1, 2. Preparation of new edition of the Coast Pilot for Alaska and Pacific coast, p. 2. Survey of oyster-beds of the Chesapeake Bay, p. 2 Synopsis of progress of work for the year, pp. 2–4. Estimates in detail for continuing work in the Eastern Division of the Coast and Geodetic Survey, pp. 4–6. Estimates for continuing work in the Western Division of the Coast and Geodetic Survey, and for surveys in aid of U. S. Geological Survey, p. 7. Estimates for repairs of vessels, publication of observations, and general expenses of all the work, p. 8. Obituary of Prof. Benjamin Peirce, pp. 8, 9; of Assistant A. M. Harrison, p. 9.

PART II —Brief abstracts of work accomplished, pp. 10–51.
*Field and office work*, progress in, pp. 10–66.
*Summary of field work*, pp. 10–51.

SECTION I.—Topography of Dyer's Neck and Petit Manan Point, coast of Maine, p. 10. Topography of Frenchman's Bay, Me., pp. 10, 11. Hydrography of the coast of Maine, near Mount Desert, p. 11. Tidal observations at North Haven, p. 11. Hydrography of Rockland Harbor, Muscle Ridge Channel, and Skilling's River, Me., pp. 11, 12. Triangulation of New Hampshire, p. 12. Triangulation of Vermont, p. 12. Primary triangulation in Vermont, pp. 12, 13. Hydrography of Pickett's Ledge, entrance to Salem Harbor, Mass., pp. 13, 14. Tidal observations at Providence, R. I., p. 14.

SECTION II.—Topography and hydrography of the south coast of Long Island, p. 14. Tidal observations on Sandy Hook, N. J., p. 15. Special operations on Hudson River, p. 15. Topography of the Hudson River, pp. 15, 16. Reconnaissance, from Lake Champlain, p. 16. Primary triangulation in New York, pp. 16, 17. Longitude observations at Cape May, N. J., p. 17. Topography and triangulation near Cape May, N. J., pp. 17, 18. Hydrography of Delaware Bay, p. 18. Triangulation of the Delaware River, pp. 18, 19. Topography of the Delaware River, p. 19. Triangulation and topography of the Delaware River, pp. 19, 20. Hydrography of the Delaware River, p. 20. Hydrography below Fort Mifflin, pp. 20, 21. Special operations on the Delaware River, p. 21. Triangulation in New Jersey, p. 21. Triangulation in Pennsylvania, pp. 21, 22.

SECTION III.—Atlantic Coast Pilot work, p. 22. Hydrography north of Chincoteague Inlet, p. 22. Special hydrography of Chesapeake Bay, pp. 22, 23. Triangulation of the District of Columbia, pp. 23, 24. Triangulation of the District of Columbia (southern portion), p. 24. Topography of the District of Columbia, pp. 24, 25. Topography of site for new Naval Observatory in the District of Columbia, p. 25. Magnetic observatory at Washington, pp. 25, 26. Permanent trial base at Fort Myer, p. 26. Pendulum observations, p. 26. Hypsometry, pp. 26, 27. Telegraphic longitudes, p. 27. Magnetic observations, p. 27. Triangulation in West Virginia, pp. 27, 28.

SECTION V.—Tidal observations at Charleston, S. C., pp. 28, 29.

SECTION VI.—Deep-sea soundings, dredgings, and temperature observations, pp. 29, 30. Triangulation, topography, and hydrography of Indian River, Florida, pp. 30, 31. Hydrography of Cape Cañaveral Shoals and south of Cape Cañaveral, pp. 31, 32.

SECTION VII.—Hydrography off Egmont Key and off Light-House Point, p. 32.

SECTION VIII.—Mississippi River survey, 32–34. Tidal observations at Lake Borgne, La., p. 34. Hydrography of the Mississippi River, p. 34. Triangulation, p. 34. Triangulation of river continued, pp. 34, 35. Geodetic leveling, p. 35. Triangulation near Vicksburg, Miss., p. 35. Triangulation near Greenville, Miss., pp. 35, 36.

SECTION IX.—Topography of the Laguna Madre, Tex., p. 36. Hydrography near Padre Island, coast of Texas, pp. 36, 37.

SECTION X.—Magnetic observations along coasts of Lower California, Mexico, and Central America, pp. 37, 38. Tidal observations at Mazatlan, Mexico, p. 38. Hydrography of part of California coast, p. 38. Topography near San Luis Obispo, Cal., pp. 38, 39. Tidal observations, San Francisco Bay, p. 39. Primary triangulation of California coast, pp. 39–41. Triangulation and topography, coast of California, pp. 41, 42. Tidal observations at the Sandwich Islands, p. 42.

SECTION XI.—Topography, triangulation, and hydrography of the Columbia River, pp. 42, 43. Special topography of the Columbia River, p. 43. Triangulation and topography of part of Puget Sound, pp. 43, 44. Hydrography o Port Discovery and adjacent waters, Strait of Juan de Fuca, W. T., p. 44. Reconnaissance in British Columbia, pp. 44, 45.

SECTION XII.—Tidal observations on Kadiak, Alaska, p. 45. Coast of Alaska, pp. 45, 46.

SECTION XIII.—Astronomical observations in Kentucky and Mississippi, p. 46. Reconnaissance in Kentucky, p. 46. Triangulation in Tennessee, pp. 46, 47.

SECTION XIV.—Triangulation in Ohio, p. 47. Magnetic observations, p. 47. Triangulation in Indiana, pp. 47, 48. Triangulation and reconnaissance in Illinois, pp. 48, 49. Triangulation in Wisconsin, p. 49. Magnetic observations at Madison, Wis., p. 49.

SECTION XV.—Primary triangulation in Missouri, pp. 49, 50. Magnetic observations, p. 50.

SECTION XVI.—Primary triangulation eastward along the Thirty-ninth Parallel in Nevada and magnetic observations, pp. 50, 51. Primary triangulation eastward from El Paso Base, p. 51.

COAST AND GEODETIC SURVEY OFFICE, pp. 51–56.

OFFICE WORK.—General and special work, pp. 51, 52. Officers in charge, pp. 51–54. Hydrographic Division, pp. 54, 64–66. Electrotyping and Photographing Division, p. 54. Miscellaneous Division, pp. 54–56. Conclusion of report, p. 56.

OFFICE REPORTS.—Computing Division, pp. 57–60. Tidal Division, pp. 61, 62. Drawing Division, pp. 62, 63. Engraving Division, pp. 63, 64. Hydrographic Division, pp. 64–66.

APPENDICES, pp. 67–469.

# CONTENTS OF APPENDICES.

Page.

No. 1. DISTRIBUTION OF SURVEYING PARTIES upon the Atlantic, Gulf of Mexico, and Pacific coasts, and interior of the United States, during the year ending June 30, 1881 .......... 67–72

No. 2. STATISTICS of field and office work of the United States Coast and Geodetic Survey for the year ending December 31, 1880 .......... 73–74

No. 3. INFORMATION furnished from the Coast and Geodetic Survey Office from original sheets, transcripts of records, &c., in reply to special calls, during the year ending June 30, 1881 .......... 75–80

No. 4. DRAWING DIVISION.—Charts completed or in progress during the year ending June 30, 1881 ..... 81–83

No. 5. ENGRAVING DIVISION.—Plates completed, continued, or commenced during the year ending June 30, 1881 .......... 84–90

No. 6. GENERAL INDEX of scientific papers, methods, and results contained in the Appendices to the Annual Reports of the United States Coast and Geodetic Survey, from 1845 to 1880, inclusive, by C. H. Sinclair, Subassistant .......... 91–123

No. 7. TYPE FORMS OF TOPOGRAPHY, Columbia River, by E. Hergesheimer, Assistant .......... 124–125

No. 8. TERRESTRIAL MAGNETISM.—Directions for magnetic observations with portable instruments, by C. A. Schott, Assistant .......... 126–158

No. 9. TERRESTRIAL MAGNETISM.—Collection of results for declination, dip, and intensity, from observations made by the United States Coast and Geodetic Survey, between 1833 and 1882, by C. A. Schott, Assistant .......... 159–224

No. 10. METEOROLOGICAL RESEARCHES.—Part III.—Barometric hypsometry and reduction of the barometer to sea-level. William Ferrel .......... 225–268

No. 11. REPORT ON THE OYSTER BEDS of the James River, Virginia, and of Tangier and Pocomoke Sounds, Maryland and Virginia, by Lieut. Francis Winslow, U. S. N., Assistant, Coast and Geodetic Survey .......... 269–353

No. 12. ON THE LENGTH of a Nautical Mile, by J. E. Hilgard, Superintendent Coast and Geodetic Survey .. 354–356

No. 13. ON A METHOD of readily transferring the underground mark at a base monument, by O. H. Tittmann, Assistant .......... 357, 358

No. 14. ON THE FLEXURE of Pendulum Supports, by C. S. Peirce, Assistant .......... 359–441

No. 15. ON THE DEDUCTION of the Ellipticity of the Earth from Pendulum Experiments, by C. S. Peirce, Assistant .......... 442–456

No. 16. ON A METHOD of observing the coincidence of vibrations of two pendulums, by C. S. Peirce, Assistant .......... 457–460

No. 17. ON THE VALUE of Gravity at Paris, by C. S. Peirce, Assistant .......... 461–463

No. 18. NEW RULE for Tides in Delaware Bay, by Henry Mitchell, Assistant .......... 464–469

# ALPHABETICAL INDEX.

A.

ABSECON INLET. Chart of, reference to, in estimates, p. 6.
ABSTRACTS OF LOCALITIES OF WORK ON ATLANTIC, GULF, AND PACIFIC COASTS, pp. 10–51.
ACAJUTLA. Magnetic observations at, p. 38.
ACAPULCO. Magnetic observations at, p. 38.
ACKLEY, S. M., LIEUTENANT, U. S. N. Hydrography of coast of Maine, near Mount Desert, p. 11; detached from duty on the Eagre, p. 65.
ADIRONDACK MOUNTAINS. Reference to, p. 17.
ADIRONDACK SURVEY. Reference to Mr. Colvin, Superintendent of the, p. 13.
ADMIRALTY INLET. Triangulation near, p. 43; computation of, p. 58.
AGASSIZ, PROFESSOR A In charge of specimens obtained in deep-sea soundings off George's Bank, p. 29.
AIDS TO NAVIGATION, p. 65.
AIKEN, MR. WALTER. Tripod erected at Mount Washington at expense of, p. 12.
ALABAMA. Compilation for map of northern part of, p. 26.
ALASKA. Reference to field work of Assistant Dall on coast of, p. 2; tidal observations in, pp. 4, 45; reference to, in estimates, p. 7; magnetic observers for, instructed at Magnetic Observatory, Washington, D. C., p. 25; observations on variation of the compass in, p. 45; reference to scientific outfit of party for, p. 58- special surveying vessel suggested for, p. 65.
ALASKA COAST PILOT. Reference to appendix to, p. 2; notes for, p. 4; reference to, in estimates, p. 7; data for, p. 45; plates for, p. 63.
ALASKA COMMERCIAL COMPANY. Tide gauge on wharf of, p. 45.
ALASKAN REGION. Magnetic chart of, obtained, p. 46.
ALDERSON, W. VA. Meteorological observations at, reference to, pp. 3, 27.
ALEUTIAN ISLANDS. Tidal observations planned for the, p. 61.
ALEXANDER CREEK. Connected with triangulation of the Mississippi River, p. 34.
ALEXANDER, W. D., SUPERINTENDENT OF GOVERNMENT SURVEY OF SANDWICH ISLANDS. Tidal observations received from, p. 42.
ALLEN, W. H., ENSIGN, U. S. N. Services in Section II, pp. 18, 20.
ALSEYA HARBOR ENTRANCE, OREGON. Chart of, p. 55.
AMERICAN CONTINENT. Plan for meteorological observatory on extreme north point of, p. 1.
AMERICAN POSSESSIONS FROM THOSE OF RUSSIA. Determination of longitude of meridian separating, p. 46.
AMES, W. C. Resignation of position in Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.
AMITYVILLE. Tidal observations at, p. 14.
AMSDEN, C. H., ENSIGN, U. S. N. Services in Section II; p. 20; and in Section III, p. 22.
ANALOSTAN ISLAND. Measurement of base line on, p. 24.
ANNUAL REPORT OF SUPERINTENDENT OF UNITED STATES COAST AND GEODETIC SURVEY, pp. 1–66; reference to last, pp. 12, 16, 46; distribution of, p. 55.
ANNUAL REPORTS OF THE UNITED STATES COAST AND GEODETIC SURVEY, FROM 1845 to 1880, INCLUSIVE. General index of scientific papers, methods, and results contained in the appendices to the, by C. H. Sinclair, Subassistant. Appendix No. 6, pp. 91–123.
ANNUAL REPORTS OF FISH COMMISSIONERS OF MARYLAND. Reference to, p. 2.
APPALACHIAN CHAIN OF MOUNTAINS. Compilation for map of part of, p. 26.
APPENDICES—Nos. 1 to 18. For titles of, see page preceding Alphabetical Index.
APPENDICES TO THE ANNUAL REPORTS OF THE UNITED STATES COAST AND GEODETIC SURVEY, FROM 1845 TO 1880, INCLUSIVE. General index of scientific papers, methods, and results contained in the, Appendix No. 6, pp. 91–123. By C. H. Sinclair, Subassistant.
APPENDIX—No. 1, pp. 67–72; No. 2, pp. 73, 74; No. 3, pp. 75–80; No. 4, pp. 81–83; No. 5, pp. 84–90; No. 6, pp. 91–123; No. 7, pp. 124, 125; No. 8, pp. 126–158; No. 9, pp. 159–224; No. 10, pp. 225–268; No. 11, pp. 269–353; No. 12, pp. 354–356; No. 13, pp. 357–358; No. 14, pp. 359–441; No. 15, pp. 442–456; No. 16, pp. 457–460; No. 17, p. 461–463; No. 18, p. 464–469.
APPENDIX—No. 11, in annual report (1880) on geodetic leveling reference to, p. 35; No. 3, reference to, pp. 54, 62; No. 4, reference to, pp. 54, 62; No. 5, referred to, p. 54; No. 7, referred to, p. 43; No. 9, of report of 1879, p. 58; No. 13, referred to, p. 26; No. 14, referred to, p. 26; No. 15, referred to, p. 26.
APPLE Triangulation station in Tennessee, p. 46.
"APPROACHES TO BLUE HILL BAY." Title of chart, referred to, p. 54
APPROPRIATIONS REQUIRED FOR WORK ON THE COAST AND GEODETIC SURVEY, pp. 4–8.
ARAGO (steamer). Use of, in Section II, p. 20; temporary use of, p. 65.
ARAGO PLATINUM KILOGRAM. Reference to, p 53.
ARC DOME, NEVADA. Triangulation station, p. 50.
ARCTIC OCEAN. Surveying party entering, through Bering Strait, p. 45.
ARCTIC REGIONS. Reference to party sent to Point Barrow, pp. 1, 41, 45, 46.
ARMY POINT, BENICIA, CAL., p. 40.
ASCENSION ISLAND. Magnetic observations at, p. 38.
ASTRONOMICAL OBSERVATIONS. Determination of azimuth of base at Greenville, Miss., and Louisville, Ky., p. 46; in Ohio, p. 47.
ATHENS, OHIO. Reference to magnetic observations at, pp. 4, 47; University at, referred to, p. 47; computation of leveling work between, and Indiana, p. 53.
ATLANTA, GA. Computation of latitude and longitude observations, p. 60.
ATLANTA BASE. Reference to, in estimates, p. 5.
ATLANTIC COAST. Progress of survey of, pp. 1–3; abstracts of work on, pp. 10–51; deep-sea work in Gulf Stream, reference to, p. 10; reference to corrections and additions to working chart of, p. 22; plotting of deep-sea soundings off the, p. 54.
ATLANTIC COAST TRIANGULATION. Reference to, in estimates, pp. 5, 58.

ATLANTIC, GULF, AND PACIFIC WORK ARRANGED IN SECTIONS. Section I, pp. 10–14; Section II, pp. 14–22; Section, III, pp. 22–28; Section V, pp. 28, 29; Section VI, pp. 29–32; Section VII, p. 32; Section VIII, pp. 32–36; Section IX, pp. 36, 37; Section XX, pp. 37–42; Section XI, pp. 42–45; Section XII, pp. 45, 46; Section XIII, pp. 46, 47; Section XIV, pp. 47–49; Section XV, pp. 49 50; Section XVI, pp. 50, 51.

ATLANTIC AND PACIFIC COASTS. Progress of geodetic work between, p. 1; reference to, in estimates, pp. 6, 7; triangulation connecting, begun by late Superintendent Prof. B. Peirce, p. 8; reference to tide tables for, p. 62.

ATLANTIC AND GULF COAST. Reference, in estimates, to charts and work on, p. 6.

ATLANTIC AND GULF COAST PILOT. Reference, to in estimates, p. 6.

ATLANTIC COAST PILOT. Compilation of future volumes of, p. 2; of index to 2d volume of, p. 22; plates for, p. 63.

ATLANTIC, GULF OF MEXICO, AND PACIFIC COASTS, AND INTERIOR OF THE UNITED STATES, DURING THE YEAR ENDING JUNE 30, 1881. Distribution of surveying parties upon the, Appendix No. 1, pp. 67–72.

ATLANTIC AND PACIFIC OCEAN LEVELS. Probable small error in computation of the, p. 32.

AVERY, R.S. In charge of Tidal Division. Report from, pp. 61, 62.

AZIMUTH. Observations of, at various points, pp. 3, 4, 17, 27, 39, 46, 49, 50; reference in estimates, p. 5; revision of, computations, p. 59

B.

BABYLON, N. Y. Soundings and tidal observations at, p. 14.

BACHE (steamer). Information furnished officers of the, p. 31; laid up at Baltimore, Md., for repairs, p. 32; relative to condition of the, p. 64.

BACHE, A. D. Reference to, p. 8; compilation of records of exploration of Gulf Stream under instruction of, p. 53.

BACHE, C. M., ASSISTANT. Topography and triangulation near Cape May, N. J., pp. 17, 18.

BACHE, G. M., (schooner). Laid up at Washington, D. C., p. 65.

BACHE, R. M., ASSISTANT. Triangulation of the Delaware River, p. 18; reference to former work on the Delaware, p. 19; triangulation and topography of the Delaware River, pp. 19, 20.

BADGER, CHARLES J., MASTER, U. S. N. Services in Section II, p. 18; in Section VI, p. 31; and in Section VII, p. 32.

BAGADUCE RIVER. Progress of survey of, pp. 2, 11.

BAHAMA BANKS. Soundings near, pp. 3, 30; sailing chart including, referred to in estimates, p. 6.

BAIRD, PROFESSOR SPENCER F., U. S. COMMISSIONER OF FISH AND FISHERIES. Reference to, p. 45.

BAKER, MARCUS, COMPUTER. Instructions given magnetic observers of the polar expedition to Alaska, &c., by, pp. 25, 58; magnetic observations on coast of Alaska, p. 45; services in Computing Division, Coast and Geodetic Survey Office, p. 58.

BALD LEDGE, N. H., p. 12.

BALTIMORE, MD. Pendulum observations at, pp. 3, 26; the schooner Scoresby laid up at, p. 24; observations to determine force of gravity, p. 26; repairs to the Bache at, p. 32; adjustment of principal triangles in vicinity of, p. 59.

BALTIMORE AND OHIO RAILROAD, p. 25.

BALTIMORE AND WILMINGTON TURNPIKE, p. 19.

BANFORD, J. W. Tidal observations at Sandy Hook, p. 15.

BARATARIA (steamer). Use of in Section VIII, p. 35; report on condition of, pp. 64, 65.

BARBOUR, PROFESSOR V. G., ACTING ASSISTANT. Triangulation of Vermont, p. 12; aiding in triangulation of New York, p. 17.

BAR HARBOR WATER WORKS, p. 11.

BARKER, J. R., DRAUGHTSMAN. Sketches of Coast of Virginia, p. 22.

BAROMETRIC HYPSOMETRY AND REDUCTION OF THE BAROMETER TO SEA-LEVEL. Meteorological researches.—Part III, by Wm. Ferrel; Appendix No. 10, pp. 225–268.

BARR J. C. Drawing Division, Coast and Geodetic Survey Office, p. 63.

BARTLE, R. F. Engraving Division, Coast and Geodetic Survey Office, p. 64.

BARTLETT, J. R., COMMANDER, U. S. N. In command of the Blake, progress in developing Gulf Stream, and survey in Gulf of Mexico and Caribbean Sea, pp. 1, 2, 29, 30.

BARTO. Triangulation station, p. 16.

BASE APPARATUS. Five meter primary, designed by C. A. Schott, assistant, pp. 51, 52.

BASE LINE. Reference to, in Mississippi and Kentucky, p. 17; reference to, Bayou Sara and Baton Rouge, p. 34; measurement of, at Greenville, Miss., pp. 35, 36; in Section X, p. 39; SE. and NW. Yolo stations, p. 40; preliminary operations for measurement of Yolo, p. 31; reconnaissance for, in British Columbia, p. 44; computation of, p. 59.

BASE MONUMENT. On a method of readily transferring the underground mark at a, by O. H. Tittmann, assistant, Appendix No. 13, pp. 357, 358.

BASSETT, R. T. Miscellaneous division, Coast and Geodetic Survey Office, p 55.

BATON ROUGE, LA. Triangulation near, pp. 3, 32, 35; reference to base at, p. 34; materials from wreck of steamer Baton Rouge taken to, p. 35.

BATON ROUGE (Steamer). Materials and outfit saved from the wreck of the, p. 35; final use of, and wreck of, pp. 35, 36; special report on, pp. 64, 65.

BAYLOR, J. B.; SUBASSISTANT. Magnetic observations in the West, and in Virginia and West Virginia, p. 27; magnetic observations in Ohio, Michigan, and Indiana, p. 47; in Minnesota, Dakota, Nebraska, and Iowa, p. 50; Computing Division, Coast and Geodetic Survey Office, p. 59.

BAY OF MAINE. Tidal observations on island in, p. 11.

BAY OF SAN FRANCISCO, CAL. Tidal stations on, p. 40.

BAYOU SARA. Triangulation near, pp. 3, 32, 34; reference to base line at, p. 34.

BEAN, DR. T. H. An attaché of the Fish Commission accompanying party to Alaska on the Yukon, p. 45.

BEARDSLEY, L. A., CAPTAIN, U. S. N., commanding U. S. S. Jamestown, Sitka; reference to, p. 45.

BEAUTY (barge). Use of, in Section II, p. 17; relative to condition of the, p. 65.

BECK, J. H. Miscellaneous division, Coast and Geodetic Survey Office, p. 55.

BEECH KNOB, VA. p. 28.

BELKOFFSKY, ALASKA, p. 45.

BELLEVUE STATION, N. Y., p. 17.

BENICIA. Coast and Geodetic Survey bench-mark at, p. 40.

BENNER, F. W. Engraving Division, Coast and Geodetic Survey Office, p 64.

BENNETT. Triangulation station, Hudson River, p. 46.

BENNY HAVEN'S. Triangulation on the Hudson, including, p. 15.

BERING STRAIT. Passage of the Yukon through, p. 45; hydrothermal section of, accomplished, p. 46.

BERLIN BRASS METER, No. 49. Reference to, p. 53.

BERMUDA. Relative to securing tidal observations at, p 61.

BESSEL-REPSOLD COMPARATORS (Nos. I and II), p. 52.

BESSEL'S SPHEROID. Clarke's spheroid adopted instead of, p. 57.

BIGELOW MOUNTAIN, N. Y., p. 17.

BIGELOW STATION, N. Y., pp. 3, 12.

BIG ROCK (station in Pennsylvania), p. 21.

BIRD, G. F., AID. Services in Section XVI, p. 51; services in Computing Division, Coast and Geodetic Survey Office, pp. 57, 59, 60.

BISMARCK, DAK. Magnetic observations at, p. 4.

BLACK RIVER, N. Y., p. 16.

BLADENSBURG, MD., p. 25.

BLAIR, H. W., SUBASSISTANT. Transferred from triangulation in Missouri to office duty in Washington, p. 49; computation and examination of standard weights and measures, pp. 53, 54, 57; Computing Division, Coast and Geodetic Survey Office, p. 57.

BLAKE (Steamer). Reference to use of, in Gulf Stream explorations and deep-sea soundings, pp. 1, 2, 29, 30; report on condition of the, p. 64.

BLOCK HOUSE. Triangulation station, p. 15.

BLUEBERRY HILL, N. Y. Triangulation station, pp. 2, 12, 13, 17.

BLUE HILL BAY. Chart of, referred to in estimates, p. 6.

BLUE RIDGE. Triangulation near, pp. 27, 28.

BOARD OF ENGINEERS FOR THPAECIFIC COAST. Report; prepared for, by Assistant Davidson, on harbors of refuge for that coast, p. 40.

BODEGA BAY. Reference to, in estimates, p. 7.

BORDEN, THOMAS P., AID. Services in Section II, p. 16; in Section XV, p. 50; in Computing Division, Coast and Geodetic Survey Office, pp. 57, 59, 60.

BOSTON. Geodetic operations near, referred to in estimates, p. 5; tidal observations at, p. 13.

BOUNDARY BAY, BRITISH COLUMBIA. Reconnaisance for primary base line site on shores of, pp. 4, 44, 45.

BOUNDARY STREET, WASHINGTON, D. C. Triangulation north of, pp. 23, 25.

BOUTELLE, C. O., ASSISTANT. Reconnaisance and triangulation in New York, p. 16.

BOUTELLE, J. B., RECORDER AND EXTRA OBSERVER. Services in Section II, p. 16; in Section VIII, p. 35; in Computing Division Coast and Geodetic Survey Office, pp. 57, 60.

BOWDITCH, NATHANIEL. Reference to, as instructor of late Prof. Benjamin Peirce, p. 8.

BOWSER, PROF. E. A. Triangulation in New Jersey, p. 21.

BOYD, C. H, ASSISTANT. Reference to former work on the Mississippi, p. 35; triangulation of Mississippi River and report on loss of the Baton Rouge, pp. 35, 36, 65; relative to base line measured near Greenville, Miss., by, p. 46; Mr. Terry ordered to join party of, p. 50.

BRADBURY, JR., BION Services as extra observer, in Section I, p. 11; in Drawing Division, Coast and Geodetic Survey Office, p, 63.

BRADBURY, LIEUTENANT, U. S. N. Reference to his report on ice fields off New England coast in 1870, '75, p. 22.

BRADFORD, GERSHOM, ASSISTANT. Reference to continuance of survey of oyster beds in Chesapeake Bay, by, pp. 2, 22, 23 services in Section III, p. 22.

BRADFORD, J. S., ASSISTANT. Continuation of work on Atlantic Coast Pilot, p. 2; special examination off Long Island and Virginia coasts for Coast Directory, p. 22; chief of Engraving Division to December 1, 1880, p. 63.

BRAID, ANDREW, SUBASSISTANT. Reference to services in Section VIII, in 1879,'80, pp. 33, 34; geodetic leveling in Louisiana, p. 35; reference to leveling party on Mississippi River, p. 48; leveling work on Potomac River, p. 53.

BRAINERD, MINN. Magnetic observations at, p 4.

BRANDYWINE SHOAL LIGHT. Progress of hydrography near, pp. 3, 18.

BRAZOS HARBOR. Survey of, and tidal observations, p. 37.

BRAZOS LIGHT-HOUSE. Soundings north of, p. 37.

BRETON ISLAND SOUND. Estimate for completion of chart of, p. 6.

BRIERY KNOB, POCAHONTAS COUNTY, W. VA., p. 28.

BRIGHT, W. T. In charge of Drawing Division, Coast and Geodetic Survey Office, report from, pp. 62, 63.

BRIGHTWOOD, D. C., p. 25.

BRISK (schooner.) Report on condition of the, p. 65; laid up at Natchez, Miss., p. 65.

BRITISH ASSOCIATION FOR ADVANCEMENT OF SCIENCE. Dr. Craig appointed to represent the Coast and Geodetic Survey at meeting of, at York, England, p. 2.

BRITISH COLUMBIA. Reconnaissance in, p. 44.

BROAD RUN ROAD. D. C., p. 23.

BROWN, S. T., ENSIGN, U. S. N. Services in Section XI, p 44.

BROWN SHOAL. Survey of, pp. 3, 18.

BUCHANAN, PROF. A. H. Triangulation in Tennessee, p. 46.

BUNKER HILL ROAD, D. C., p. 25.

BURTON, A. E. Drawing Division, Coast and Geodetic Survey Office, p. 63.

BUTCHER'S CREEK. Special survey of, p. 23.

"BUOY OF THE MIDDLE," PORT OF PHILADELPHIA. Redetermination of position of, p. 18.

C.

CAHTO, CAL. Triangulation station, pp. 4, 39.

CAIPICOS, p. 39.

CALIFORNIA. Progress of work on new edition of Coast Pilot for p. 2; reference to, in estimates, p. 7; triangulation of coast of, pp. 4, 39, 41; referred to in estimates, p. 7: off-shore soundings, reference to, in estimates, p. 7; hydrography of coast of, p. 38; magnetic observations at points in, p. 50; new base apparatus forwarded to, p. 52.

CALL, G. W., OF FORT ROSS, CAL., p, 42.

CAMBRIDGE, MASS. Death of Prof. Benjamin Peirce, late consulting geometer, United States Coast and Geodetic Survey at, p. 8.

CAMPBELL PROF. J. L. Reconnoissance and triangulation in Indiana, pp. 47, 48.

CANADA. Reconnaissance extending into, p. 17; reference to Lieutenant Very's magnetic trip to, p. 25.

CANADIAN GOVERNMENT. Consent of the, for reconnaissance on and near Boundary Bay, British Columbia, p. 44.

CAPE CAÑAVERAL, FLA. Soundings off, p. 3; chart of coast near, referred to in estimates, p. 6; hydrography south of, p. 31.

CAPE CAÑAVERAL SHOALS. Survey of, p. 31.

CAPE CHARLES, VA., pp. 3, 22.

CAPE COD, MASS. Reference to, in estimates, p. 5; chart of, referred to in estimates, p. 6; plotting of soundings off, p. 54.

CAPE FEAR. Hydrography near, referred to in estimates, p. 5.

CAPE FEAR RIVER. Soundings at entrance, referred to in estimates, p. 5; chart of, referred to in estimates, p. 6.

CAPE FLORIDA. Deep-sea soundings, &c., off, referred to in estimates, p. 5; chart of coast near, reference to, in estimates, p. 6.

CAPE HATTERAS. General chart of coast near, referred to in estimates, p. 6; soundings and dredgings off, p. 29.

CAPE HENLOPEN. Reference to, in estimates, p. 5; reference to extension of shore line at, p. 18.

CAPE HENRY, VA. p. 3; reference to, in estimates, p. 5; views of, for Coast Pilot, p. 22.

CAPE KRUSENSTERN, ARCTIC COAST, p. 46.

CAPE LISBURNE, ARCTIC OCEAN, p. 45.

CAPE LOOKOUT. Reference to, in estimates, p. 5; dredging and soundings near, p. 29.

CAPE MANAN. Referred to in estimates, p. 5.

CAPE MAY, N. J. Longitude signals between, and Washington, p. 3; chart of, referred to in estimates, p. 6; longitude observations at, pp. 17, 27; topography and triangulation near, pp. 17, 18; shoal reported near; shoal-spot *not* found, p. 18; resurvey of shoal off, required, p. 18.

CAPE MENDOCINO. Reference to, in estimates, p. 7.

CAPE ROMAIN. Chart of coast from Hatteras to, referred to in estimates, p. 6; dredging near, p. 29.

CAPERTON, W. B., ENSIGN, U. S. N. Services in Section VIII, p. 34; in Section IX, p. 37.

CAPE SABLE. Chart of, referred to in estimates, p. 6.

CAPE SAN BLAS. Chart of coast near; reference to, in estimates, p. 6.

CAPE SEBASTIAN. Reference to, in estimates, p. 7.

CARIBBEAN SEA. Remarks on progress of explorations in, pp. 1, 2; deep-sea soundings in, reference to, in estimates, p. 5; plotting of deep-sea soundings in, p. 54.

CARROLL, CAPTAIN JAMES. Command of steamer to Sitka; facilities extended officers of Coast and Geodetic Survey, p. 45.

CARROLLTON, LA. Geodetic leveling completed near, pp. 32–33; reference to, p. 57.

CARSON SINK, STATION, NEVADA, p. 50.

CASE'S INLET, PUGET SOUND, p. 43.

CASTLETON, IND. Triangulation near, p. 47.

CASWELL (schooner). Hydrographic inspector advises sale of, p. 65.

CATALINA (schooner). Hydrographic inspector advises sale of, p. 65.

CEDAR KEYS. Reference to, in estimates, p. 5; chart of coast near, referred to in estimates, p. 6.

CENTRAL AMERICA. Magnetic stations on coast of, pp. 3–37.

CENTRALIA, COLUMBIA COUNTY, PENN., p. 21.

CERROO ISLAND. Magnetic observations on, p. 38.

CHAMPERICA. Magnetic observations at, p. 38.

CHANDELEUR SOUND. Coast chart of, referred to, in estimates, p. 6.

CHARLESTON, S. C. Tidal observations and deep-sea soundings at, pp. 3, 28, 29, 30.

CHARLESTOWN, W. VA. Observatory erected at, and magnetic observations, pp. 3, 27.

CHARLOTTE HARBOR. Triangulation of, referred to in estimates, p. 5.

CHARTS COMPLETED OR IN PROGRESS DURING THE YEAR ENDING JUNE 30, 1881. Drawing division, Appendix No. 4, pp. 81, 83.

CHEEVER, N. Y. Triangulation station, pp. 2, 12, 13, 17.

CHERNOFFSKY HARBOR, UNALASHKA, HARBOR OF REFUGE FOR THE YUKON, p. 46.

CHESAPEAKE BAY. Relative to examination of oyster beds in, pp. 2, 3, 22, 23; see also Appendix No. 11; to connect Atlantic Coast triangulation with, reference to, in estimates, p. 5; tidal observations in, referred to in estimates, p. 5; relative to report on density of waters of, p. 54.

CHESCONNESSEX CREEK, p. 23.

CHESTER, C. M., COMMANDER, U. S. N. In charge of Hydrographic Division, Coast and Geodetic Survey Office, p. 54; report from, pp. 64–66.

CHESTER CITY, PENN., pp. 3, 19, 20.

CHESTER ISLAND AND CHESTER ISLAND BAR. Relative to, pp. 19, 20.

CHILKAHT, ALASKA. Progress of observations and soundings near, p. 4; special expedition to, p. 45.

CHINCOTEAGUE BAY, pp. 22, 54.

CHINCOTEAGUE INLET. Survey of, p. 3; hydrography north of, pp. 22, 23.

CHINCOTEAGUE SHOALS. Resurvey directed, pp. 23, 54.

CHRISTIE, ALEX. S. Computing Division, Coast and Geodetic Survey Office, pp. 58, 59.

CINCINNATI, OHIO. Observatory erected at, and telegraphic longitude observations, pp. 4, 47, 48; triangulation near, p. 47.

CITY POINT. Chart of James River, Va., to, referred to in estimates, p. 6.

CLARION ISLAND, PACIFIC COAST. Magnetic observations on, p. 37.

CLARK, JOHN, MECHANICIAN. [Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

CLARKE'S MOUND, ILL. Triangulation station, p. 48.

CLARKE'S SPHEROID, pp. 57, 60.

CLARKSBURG, VA. Magnetic observations at, pp. 3, 27.

CLARVOE, G. W. Carpentry work, Coast and Geodetic Survey Office, p. 55.

CLEVELAND, OHIO. Magnetic observations at, pp. 4, 47.

CLUB-HOUSE WHARF, JAMAICA BAY, L. I. Temporary tide-gauge at, p. 14.

COAST AND GEODETIC SURVEY. Remarks on progress and condition of the, for the year ending June 30, 1881, pp. 1–4; officers and office work, pp. 51–56; estimates for field and office work of, pp. 4–8; general estimates for repairs and outfits of vessels of, p. 8; represented at meeting of British Association for advancement of science, by Dr. Thos. Craig, p. 2; surveys in aid of U. S. Geological Society, referred to in estimates, p. 7; for general expenses of, referred to in estimates, p. 8; statistics of field and office work of the, for the year ending December, 31, 1880; see Appendix No. 2, pp. 73, 74.

COAST AND GEODETIC SURVEY'S BENCH-MARK AT WEST POINT, N. Y. Referred to, p. 16.

COAST AND GEODETIC SURVEY'S MAGNETIC OBSERVATORY AT MADISON, WIS., p. 58.

COAST AND GEODETIC SURVEY OFFICE. Officers and employés, pp. 51–56; meter pendulums for Arctic explorers prepared at, p. 26; information furnished from, from original sheets, transcripts of records, &c., in reply to special calls during the year ending June 30, 1881; see Appendix No. 3, pp. 75–80.

COAST AND GEODETIC SURVEY. Reference to primary triangulation of the, pp. 25, 26, 27.

COAST DIRECTORY FOR SMALL CRAFT Relative to compilation of, p. 22.

COAST OF ALASKA. Reference to explorations on, pp. 1, 45; progress of sounding off, p. 4.

COAST PILOT (ATLANTIC) WORK, p. 22; distribution of copies of, p. 55.

COAST PILOT. Progress of work on, p. 2; views of Columbia River, Oregon, for, p. 4; reference to, in estimates, pp. 6, 7.

COAST PILOT OF ALASKA. Progress of collecting notes for, p. 4; reference to, in estimates, p. 7; special expedition to obtain data, for the, p. 45.

COFFIN, FREDERICK W., ENSIGN, U. S. N. Services in Section X, p. 38.

COHANSEY CREEK, p. 3.

COHANSEY LIGHT. "Five-foot spot" near, not now existing, p. 18.

COLBY, H. G. O., LIEUTENANT, U. S. N., ASSISTANT. Coast and Geodetic Survey, hydrography of Rockland Harbor, Muscle Ridge Channel and Skilling's River, Me., p. 11; hydrography of Pickett's Ledge, entrance to Salem Harbor, Mass., p. 13; ordered to command of the schooner Eagre, p. 65.

COLE, MO. Triangulation station, pp. 49, 50.

COLLECTION OF RESULTS FOR DECLINATION, DIP, AND INTENSITY, FROM OBSERVATIONS MADE BY THE U. S. COAST AND GEODETIC SURVEY BETWEEN 1833 AND 1882. By C. A. Schott, Assistant, Appendix No. 9, pp. 159–224.

COLLINS, FREDERICK, LIEUTENANT, U. S. N. Examination of oyster-beds of Chesapeake Bay, p. 2.

COLONNA, B. A., ASSISTANT. Geodetic leveling in California, by, p. 40; services in Section X, p. 40; Yolo base line, p. 41.

COLORADO. Primary triangulation extended in, pp 4, 51; reference to in estimates, p. 7.

COLORADO SPRINGS. Triangulation near, p. 51.

COLUMBIA CITY, OREG., pp. 4, 42.

COLUMBIA RIVER. Progress of survey of, p. 4; referred to in estimates, p. 7; topography, triangulation, and hydrography of, pp. 42, 43; special topography of the, p. 43; type forms of topography, by E. Hergesheimer, Assistant; Appendix No. 7, pp. 124, 125

COLUMBUS, CHRISTOPHER. Reference to his first voyage, p. 58.

COLUMBUS, OHIO. Triangulation near, p. 47.

COLUSA. Examination for co-efficient of refraction near, p. 40.

COLVIN, MR. VERPLANCK. Superintendent of the Adirondack Survey; information given by, p. 13.

COMMISSION OF FISH AND FISHERIES. Of State of Maryland, relative to annual report of, p. 2; of the United States dredging for, reference to in estimates, p. 5; at request of U. S. an attaché of that service accompanying party to Alaska, p. 45.

COMPUTING DIVISION OF COAST AND GEODETIC SURVEY OFFICE. Report from, by Assistant C. A. Schott, in charge of, pp. 57, 60; reference to certain work for, p. 28; resumé of leveling operations on Mississippi River, furnished from the, pp. 32, 33, 35.

CONGRESS OF THE UNITED STATES. Estimates for work on the Coast and Geodetic Survey submitted to, pp. 4–8; special appropriation by, for re-survey of Delaware River, p. 18.

CONNECTICUT RIVER. Reference to, in estimates, p. 5.

COOK'S INLET, p. 45.

COOPER, W. W., ASSISTANT IN OFFICE OF SUPERINTENDENT. Retired owing to failing health, p. 56.

CORNELL'S CREEK, JAMAICA BAY, p. 2. Survey of, p. 14.

CORNWALL, HUDSON RIVER. Survey near, p. 15.

CORNWALL, P. B., AGENT OF STEAMER TO SITKA. Courtesies extended by, p. 45.

CORNWELL, CHARLES C., LIEUTENANT, U. S. N. Services in Section VI, p. 30.

CORPUS CHRISTI, TEX. Topography near, p. 3; reference to in estimates, p. 5.

CORPUS CHRISTI BAY. Chart of coast of, referred to in estimates, p 6.

CORPUS CHRISTI INLET. Soundings in, p. 37.

CORY'S PEAK, NEV., p. 50.

COURTENAY, EDWARD H. Computing Division, Coast and Geodetic Survey Office, pp. 58, 59.

COURTENAY, F. Engraving Division, Coast and Geodetic Survey Office, p. 64.

COVINGTON, VA. Magnetic observations at, pp. 3, 27.

COX, G. F. Carpentry work, Coast and Geodetic Survey Office, p. 55.

COZZEN'S DOCK, HUDSON RIVER. Topography near, p. 15.

CRAIG, DR. THOMAS. Representing Coast and Geodetic Survey at meeting of British Association for Advancement of Science, at York, England, p. 2; Tidal Division, Coast and Geodetic Survey Office, p. 62.

CRAMER'S GULCH, COLO., p. 51.

CRESCENT CITY. Survey near, referred to in estimates, p. 7.

CRESSE, N. J. Triangulation station, p. 18.

CRISFIELD, MD. Relative to oyster-beds near, p. 23.

CROSS SOUND, ALASKA, p. 45.

CROWN POINT, N. Y. Triangulation near, p. 13.

CROW'S NEST MOUNTAIN, N. Y., p. 15.

CUBE, N. H. Triangulation station, p. 12.

CULVER'S GAP, N. J., p. 21.

CUMBERLAND SOUND. General chart of coast of, referred to ni estimates, p. 6.

CURRENT OBSERVATIONS. Reference to, p. 1; referred to in estimates, p. 7.

CURRITUCK LIGHT-HOUSE, N. C. Soundings near, pp. 3, 30.

CUTTS, R. D., ASSISTANT. Triangulation of Vermont, p. 12; primary triangulation in Vermont, pp. 12, 13; reference to, p. 16; primary triangulation in New York, pp. 16, 17.

D.

DAKOTA. Magnetic observations in, pp. 27, 50.

DALL, W. H., ASSISTANT. Reference to Appendix to Alaska Coast Pilot by, p. 2; self-registering tide-gauge taken to Kadiak, Alaska, by, p. 45; data for Alaska Coast Pilot, p. 45.

DALLES. Topography of Columbia River, including the, pp. 4, 43.

DARTMOUTH COLLEGE, p. 12.

DAVIDSON, GEORGE, ASSISTANT. Relative to new edition of Coast Pilot for California, Oregon, and Washington Territory, in preparation by, p. 2; in charge of office at San Francisco; relative to tidal observations, p. 39; primary triangulation, Yolo Base, pp. 39, 40, 41.

DAVIDSON QUADRILATERALS. Reference to, p. 50.

DAVIES, PROF. J. E. Triangulation in Wisconsn, p. 49; temporary charge of observations at Madison, Wis., pp. 49, 58.

DAVIS, W. H. Engraving Division, Coast and Geodetic Survey Office, p. 64.

DEAN, G. W., ASSISTANT. Longitude observations at Cape May, N. J., p. 17; telegraphic longitudes at Washington, p. 27; astronomical observations at various points inspected by, p. 47.

DEATHS. Prof. Benjamin Peirce, Consulting Geometer, pp. 8, 9; A. M. Harrison, Assistant, p. 9; C L. Drinkard, clerk in office of Superintendent, and in Engraving Division, Coast and Geodetic Survey Office, pp. 56, 64.

DECLINATION. Magnetic observations for, pp. 4, 38; progress of observations for, on coasts of Central America, Mexico, and Lower California, p. 3; terrestrial magnetism, collection of results for dip and intensity, from observations made by the United States Coast and Geodetic Survey between 1833 and 1882, July; Appendix No. 9, pp. 159–224.

DEEP-SEA SOUNDINGS, DREDGINGS, AND TEMPERATURE OBSERVATIONS, pp. 29, 30.

DELAWARE. Hydrography of inland waters on coast of, pp. 3, 22.

DELAWARE BAY. Progress of soundings in main ship channel of, p. 3; estimates for completing survey of, p. 6; hydrography of, p. 18; new rule for tides in, by Assistant Henry Mitchell; Appendix No. 18, pp. 464–469.

DELAWARE CITY, p. 18.

DELAWARE RIVER. Progress of triangulation of, pp. 3, 18, 19; chart of, reference to, in estimates, p. 6; estimate for completion of survey of, p. 6; topography of, p. 19; triangulation and topography of, pp. 19, 20; hydrography of, p. 20; stations near, recovered and marked, p. 21.

DELTA BASE, MISSISSIPPI RIVER, p. 35.

DENNIS, W. H., ASSISTANT. Reference to former work on Mississippi River by, p. 34; triangulation of Mississippi River, pp. 34, 35.

DENVER, COLO., p. 51.

DENVER AND RIO GRANDE RAILROAD. Line of levels near track of, p. 51.

DEPOT. SE. base. Triangulation station, p. 34.

DEVOL, PROF. R. S. Triangulation in Ohio, p. 47.

DIABLO-SHASTA. Experiments for co-efficient of refraction on line, p. 40.

DICKENS, E. F., SUBASSISTANT. Services in Section X, p. 40.

DIOMEDE ISLANDS, BERING STRAIT. Station established on, p. 46.

DIRECTIONS FOR MAGNETIC OBSERVATIONS WITH PORTABLE INSTRUMENTS. Terrestrial magnetism; Appendix No. 8. pp. 126–158.

DISTRIBUTION OF SURVEYING PARTIES UPON THE ATLANTIC, GULF OF MEXICO, AND PACIFIC COASTS, AND INTERIOR OF THE UNITED STATES, DURING THE YEAR. ENDING JUNE 30, 1881. Appendix No. 1. pp. 67–72.

DISTRICT OF COLUMBIA. Progress of triangulation of, and topography, pp. 3, 23, 24, 25; topography of site for new naval observatory in the, p. 25.

DOGFISH BAY. Triangulation of Port Orchard, including, p. 43.

DOLGOI ISLAND. Magnetic observations on, p. 45.

DONALDSONVILLE, LA. Hydrography of Mississippi River near, pp. 3, 32, 33.

DONN, F. C., AID. Services in Section III, p. 25; Hydrographic Division, Coast and Geodetic Survey Office, pp. 54, 66.

DONN, J. W., ASSISTANT. Topography and hydrography of the southern coast of Long Island, p. 14; survey of District of Columbia, p. 15; topography of the District, p. 24.

DOOLITTLE, MYRICK H. Computing Division, Coast and Geodetic Survey Office, p. 59.

DOWNES, J. Tidal Division, Coast and Geodetic Survey Office, p, 62.

DRAWING DIVISION. Report from pp. 62, 63; work done in the Hydrographic Division for the, p. 66; charts completed or in progress during the year ending June 30, 1881; Appendix No. 4, pp. 81–83.

DREDGING OPERATIONS, pp. 1, 2, 20, 30, 54.

DREYER, ILL. Triangulation station, p. 48.

DRIFT (schooner). Laid up for want of means to put in service p. 65.

DRINKARD, C. L. In office of superintendent, p. 55; notices of death of, pp. 56, 64; services in Engraving Division, Coast and Geodetic Survey Office, p. 64.

DUBUQUE, IOWA. Magnetic observations at, p. 4.

DUPONT, D. C. Triangulation station, p. 24.

DYER'S BAY, ME., p. 10.

DYER'S NECK, ME. Progress of work near, p. 2; topography of, p. 10.

DYER'S INLET. Triangulation of Port Orchard, including, p. 43.

E.

EAGLE HILL, DYER'S NECK, ME., p. 10.

EAGRE (schooner). Use of, in Section I, pp. 11, 12, 13; report on condition of, p. 65.

EARNEST (schooner). Use of, in Section XI, p. 44; report on condition of, p. 65.

EASTERN DIVISION OF COAST AND GEODETIC SURVEY for the year ending June 30, 1883, reference to, in estimates, p. 6.

EASTERN FLORIDA. Progress of topography and hydrography of, p. 3; reference to, in estimates, p. 5.

EASTERN SIBERIA, p. 45.

EASTPORT, ME. Positions of new light-houses on coast between New York and, reference to, in estimates, p. 5.

EDGEMOOR, DELAWARE RIVER. Progress of hydrography near, pp. 3, 20.

EGGEMOGGIN REACH. To finish chart of, reference to, in estimates, p. 6.

EGMONT KEY. Progress of soundings near, pp. 3, 31; hydrography off, p. 32.

EICHHOLTZ, H. Drawing Division, Coast and Geodetic Survey Office, p. 63.

EIMBECK, WILLIAM, ASSISTANT. Primary triangulation eastward along the 39th parallel in Nevada, and magnetic observations, pp. 50, 51.

ELDRIDGE. Triangulation station, p. 18.

ELD INLET, p. 43.

ELECTROTYPING AND PHOTOGRAPHING DIVISION, COAST AND GEODETIC SURVEY OFFICE, p. 54.

ELLICOTT, EUGENE, ASSISTANT. Triangulation and topography of Port Orchard and Puget Sound, p. 43.

ELLICOTT, W. P., MASTER, U. S. N. Services in Section X p. 38.

ELLIPTICITY OF THE EARTH FROM PENDULUM EXPERIMENTS. On the deduction of the, by C. S. Peirce, Assistant, Appendix No. 15, pp. 442–456.

EL PASO BASE. Primary triangulation in Colorado extended east from, pp. 4, 51.

ENDEAVOR (steamer). Use of, in Section II, p. 18; reference to use of, in Sections VI, VII, p. 18; report on condition of, pp. 64, 65.

ENGINEER BUREAU. Work in the Electrotyping and Photographing Division for the, p. 54.

ENGINEER COMMISSION. OF THE D. C. Special topographical work at request of, p. 25.

ENGRAVING DIVISION, COAST AND GEODETIC SURVEY OFFICE. Assistant Ogden assigned to charge of, p. 10; report from, pp. 63, 64; plates completed, continued, or commenced during the year ending June 30, 1881: Appendix No. 5, pp. 84–90.

ENTHOFFER, J. Engraving Division, Coast and Geodetic Survey Office, p. 64.

ERICHSEN, P. Drawing division, Coast and Geodetic Survey Office, p. 63.

ESHLEMAN, E., MECHANICIAN. Miscellaneous Division, Coast and Geodetic Survey Office, p, 55.

ESTIMATES, pp. 4–8.

EVANS, H. C. Engraving division, Coast and Geodetic Survey Office, p. 64.

**F.**

FAIRFIELD, G. A., ASSISTANT. Measurement of base in Kentucky, p. 46; triangulation and reconnaissance in Illinois, p. 48; services in Coast and Geodetic Survey Office, p. 52.

FAIRFIELD, W. B., EXTRA OBSERVER. Services in Section III, p. 28; office duty, p. 54.

FARQUHAR, H. Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.

FATHOMER (steamer.) Laid up at Washington, D. C., sale of, advised, p. 65.

FAUNTLEROY (schooner.) Use of, in Section XI, p. 44; and sale of, pp. 44, 45.

FAUTH & CO., OF WASHINGTON. Self-registering tide-gauge by, p. 34; micrometer microscope direction instrument made by, p. 34.

FEDERAL POINT, FLA. Reference to, in estimates, p. 6.

FENNER. Primary station, p. 16,

FERREL, PROF. WILLIAM. Reference to paper on hypsometry by, p. 2; meteorological researches, part III; barometric hypsometry and reduction of the barometer to sea-level; Appendix No. 10, pp. 225–268, by.

FIELD AND OFFICE WORK OF THE UNITED STATES COAST AND GEODETIC SURVEY FOR THE YEAR ENDING DECEMBER 31, 1880. Statistics of, Appendix No. 2, pp. 73, 74.

FIELD OPERATIONS IN COURSE OF THE FISCAL YEAR ENDING JUNE 30, 1881, pp. 2–4. Estimates for, year ending June 30, 1883, pp. 5–7.

FIELD'S HILL, VT. Triangulation observations completed at, pp. 2, 13.

FIRE ISLAND. Survey of, p. 14.

FISCHER, LOUIS. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

FISH AND FISHERIES. U. S. Commission on, reference to, in estimates, p. 5; attaché of, accompanying party on Yukon to Alaska, p. 45.

FISH COMMISSIONERS OF STATE OF MARYLAND. Relative to oyster-beds in Chesapeake Bay in annual reports of, p. 2.

FISHER, W. T. Tidal observations at Kadiak, Alaska, by, p. 45.

FLEXURE OF PENDULUM SUPPORTS. On the, by Assistant C. S. Peirce, Appendix No. 14, pp. 359–441.

FLORENCE. Primary station, p. 16.

FLORIDA. East coast of, triangulation of, pp. 3, 30–32; reference to, in estimates, p. 5; western coast of, p. 32; reference to, in estimates, p. 5.

FLYNNE, LUCIEN, ENSIGN, U. S. N. Services in Section VI, p. 30.

FORNEY, STEHMAN, ASSISTANT. Reconnaissance on shores of Boundary Bay, British Columbia, for primary base-line site, p. 44.

FORT ADAMS. Bench-mark XLIX, p. 33

FORT MIFFLIN. Topography of Delaware River near, pp. 3, 19; hydrography below, p. 20.

FORT MYER, D. C. Triangulation near, pp. 3, 24; permanent trial-base at, p. 26.

FORT RENO, D. C., p. 23.

FORTRESS MONROE, VA., p. 22.

FORT ROSS, CAL., p. 42.

FORT SNELLING, MINN. Magnetic observations at, pp. 4, 50.

FORT SUMTER, S. C. Tidal observations at, p. 29.

FORT WHIPPLE, now FORT MYER, D. C., p. 24.

FOURTEEN FOOT BANK. Survey of shoal near, pp. 3, 18.

FOURTEENTH STREET, EXTENDED. Triangulation of the D. C., p. 25.

FOWLER, E. H., Drawing Division, Coast and Geodetic Survey office, p. 63.

FRANKLIN, ME., AT HEAD OF FRENCHMAN'S BAY, p. 11.

FRANKLIN, VA., p. 22.

FRANKLIN BAY, ME. Progress of survey of, pp. 2–11.

FRASER RIVER, p. 44.

FREEPORT, L. I., p. 14.

FRENCH, W. B. In office of Assistant in charge of Coast and Geodetic Survey Office, p. 55

FRENCHMAN'S BAY, ME. Progress of survey of shores and upper heads of, pp. 2, 10; reference to, in estimates, p. 5; chart of, referred to in estimates, p. 6; topography of, pp. 10, 11.

**G.**

GALT, R. H., MASTER, U. S. N. Services in Section X, p. 38.

GALVESTON, TEX. Chart of coast near, reference to, in estimates, p. 6; arrival of the Gedney at, p. 36.

GARDNER, JAMES T. Primary triangulation of New York-State survey, by, p. 16.

GARST, PERRY, LIEUTENANT, U. S. N. Hydrography of Port Discovery and adjacent waters, Strait of Juan de Fuca, W. T., p. 44.

GEDNEY (steamer). Use of, in Section VIII, p. 34; in Section IX, p. 36; report on condition of, p. 64;

GEDNEY, C. D. Clerk in office of Assistant in charge of Coast and Geodetic Survey, p. 55.

GENERAL INDEX OF SCIENTIFIC PAPERS, METHODS AND RESULTS CONTAINED IN THE APPENDICES TO THE ANNUAL REPORTS OF THE U. S. COAST AND GEODETIC SURVEY FROM 1845 TO 1880, INCLUSIVE, BY C. H. SINCLAIR, SUBASSISTANT. Appendix No 6, pp. 91–123.

GENOA CONE, NEV., p. 50.

GEODETIC LEVELING. p, 35.

GEODETIC OPERATIONS. Reference to, in estimates, p. 6; in the Sierra Nevada, pp. 4, 50, 51; in New Hampshire, p. 12; in Vermont, pp. 12, 13; in New York, p. 16; on Delaware River, pp. 18, 19; on Hudson River, p. 21; in Pennsylvania, p. 21; in District of Columbia, pp. 23, 24; in West Virginia, p. 27; on Mississippi River, p. 35; in connection with Yolo Base, pp. 39–41; in British Columbia, p. 44; in Kentucky, p. 46; in Tennessee, pp. 46, 47; in Ohio, p. 47; in Indiana, pp. 47, 48; in Illinois, p. 48; in Wisconsin, p. 49; in Missouri, pp. 49, 50; from El Paso base, p. 51.

GEOFFRY. Station in Illinois, p. 48.

GEOGRAPHICAL ENUMERATION OF COAST AND GEODETIC SURVEY WORK, pp. 2–4, 10–51.

GEOLOGICAL SURVEY. Surveys in aid of the U. S., referred to in estimates, p. 7.

GEORGE, W. E., PILOT OF SITKA STEAMER, p. 45.

GEORGE'S BANK. Progress of deep-sea soundings between, and Charleston, S. C., pp. 3, 29.

GEORGETOWN, D. C. Reference to location of new Naval Observatory near, p. 25.

GEORGIA. Compilation of map of northern parts of, p. 26; extension of oblique arc along the Atlantic coast from Maine to, p. 58.

GERDES, F. H., ASSISTANT. Special operations on the Hudson, pp. 15, 21.

GILBERT, J. J., ASSISTANT. Assigned to Computing Division, Coast and Geodetic Survey Office, pp. 53, 57, 60.

GILE HILL, VT. Station, p. 2.

GILLESPIE, G. L., LIEUT. COL., CORPS OF ENGINEERS. Data relative to Columbia River forwarded by Assistant Rockwell to, p. 43.

GILLMORE, Q. A., GENERAL, U. S. A. Tide gauge at Charleston, S. C., furnished at request of, p. 28.

GLENORA, MISS. Progress of triangulation of Mississippi River near, p. 3.

GLYNDON, MINN. Magnetic observations at, pp. 4, 50.

GOLDEN GATE. Tidal and current observations at, referred to in estimates, p 7.

GOMERA, MADEIRA ISLAND. Reference to, p. 58.

GOMMER'S HILL, LEWIS COUNTY, N. Y., p. 16.

GOODFELLOW, EDWARD, ASSISTANT. In office of the Assistant in charge of the Coast and Geodetic Survey Office, p. 51.

GRABENHORST, W. H. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

GRAHAM, A. B. Drawing Division, Coast and Geodetic Survey Office, p. 63.

GRAND HAVEN, MICH. Magnetic observations at, pp. 4, 47.

GRANGER, F. D., ASSISTANT. Reference to stations established by, p. 34; primary triangulation in Missouri, p. 49.

GRATIOT'S GROVE, WIS. Station, p. 49.

GRAVITY. On the value of, at Paris, by Assistant C. S. Peirce, Appendix No. 17, pp. 461–463.

GRAY, E. Tidal observations at Saucelito, Cal., p. 39.

GREAT AMERICAN BOTTOM, p. 48.

GREAT SOUTH BAY, L. I. Chart of, referred to in estimates, p. 6; hydrography of, p. 14.

GREELY, A. W., LIEUTENANT, U. S. A. In charge of party to Lady Franklin's Bay, p. 26.

GREEN COVE SPRINGS, FLA. Reference to, in estimates, p. 6.

GREENE, B. D., LIEUTENANT, U. S. ENGINEER CORPS. Tidal observations at Charleston, S. C. by, p. 28.

GREENLAND. Magnetic outfit for explorers north of, p. 58.

GREENVILLE, MISS. Triangulation of Mississippi River near, and azimuth determined at base line, pp. 3, 17, 32, 35; measurement of base line near, pp. 35, 46, 59; Rescued property of wrecked steamer Baton Rouge stored at, p. 36; computation of levelings of precision of, pp. 57, 59.

GREENVILLE BENCH-MARK, p. 33.

GREENWELL, W. E., ASSISTANT. Topography near San Luis Obispo, Cal., pp. 38, 39.

GREENWICH, ENGLAND, p. 58.

GRUBB'S LANDING, DELAWARE RIVER, p. 19.

GUADALUPE ISLAND. Reconnaissance on, pp. 3, 4; magnetic observations on, pp. 37, 38.

GUAYAMAS. Magnetic observations at, p. 38.

GULF COAST. Progress in triangulation of, pp. 1, 2; estimates for, p. 6; chart of, referred to in estimates, p. 6.

GULF OF MEXICO. Astronomical and magnetic observations throughout the, reference to, in estimates, p. 5; chart of, p. 62; referred to in estimates, p. 6; reference to natural walls of sand found on shores of, p. 10; triangulation of Mississippi River between Helena, Ark., and, p. 32; model of, from recent deep-sea soundings, p. 62.

GULF STREAM. Progress of development of, and deep-sea soundings in, pp. 1, 29, 30; reference to, in estimates, p. 5; noticed under head of Section VI, p. 10. Relative to "strong rip" a mile in width in, p. 30; preparations for publication of explorations in,—made under instructions of late Superintendent A. D. Bache, p. 53.

H.

HACK'S ROCK, NEAR WOODY ISLAND, p. 23.

HALL, TENN. Station, p. 46.

HALTER, R. E., ASSISTANT. Topography of coast of Texas, p. 36.

HAMBURG, N. J. Station, p. 21.

HAMMERSLEY'S INLET, p. 43.

HAMPDEN, ME. Hydrography of Penobscot River near, pp. 2, 11.

HAREWOOD ROAD. Triangulation of the District, of Columbia, p. 25.

HARKER, WIS. Triangulation station, p. 49.

HARRISON, A. M., LATE ASSISTANT, COAST AND GEODETIC SURVEY. Obituary of, p. 9.

HARROD, GENERAL B. M., STATE ENGINEER OF LOUISIANA. Self-registering tide-gauge furnished to, p. 34.

HARTFORD, CONN. Survey of the river at; reference to, in estimates, p. 5.

HASSLER, (steamer). Use of, Section X, pp. 37, 38; report on condition of, pp. 64, 65.

HAUPT, PROF. L. M., ACTING ASSISTANT. Triangulation in Pennsylvania, p. 21; regret at his resignation, and successor nominated, pp. 21, 22.

HAVEN'S NECK, CAL., p. 41.

HAYCOCK, N. J., p. 21.

HEARD, MO. Station, pp. 49, 50.

HEILNER, L. C., LIEUTENANT, U. S. N. Services in Section X, p. 38.

HEIN, SAMUEL, LIBRARIAN, COAST AND GEODETIC SURVEY OFFICE, p. 55.

HELENA, ARK., p. 32.

HEMPSTEAD BAY, L. I. Chart of; referred to in estimates, p. 6.

HENDERSON, C. W. Computing division, Coast and Geodetic Survey Office, pp. 57, 60.

HENDERSON, MISS., p. 35.

HERBERT, W. A. In office of Assistant in charge of Coast and Geodetic Survey Office, transferred to Office of Disbursing Agent, p. 55.

HEREFORD LIGHT, N. J., pp. 17, 18.

HERGESHEIMER, E., ASSISTANT. Special topography of the Columbia River, p. 43; services in Coast and Geodetic Survey Office, "Treatise on the Plane Table," p. 52; Type Forms of Topography, Columbia River, by—Appendix No. 7, pp. 124, 125.

HERGESHEIMER, JOSEPH, SUBASSISTANT. Survey of Delaware River, p. 19.

HERON LAKE, MINN. Magnetic observations at, pp. 4, 50.

HERRICK, VT. Station, pp. 2, 12.

HIGHGATE. Triangulation station, p. 17.

HIGHLAND FALLS, N. Y., p. 15.

HIGH MOUNT, N. J., p. 21.

HIGH POINT, MO. Station, p. 49.

HILGARD, J. E., SUPERINTENDENT U. S. COAST AND GEODETIC SURVEY. Submitting to the Hon. Secretary of the Treasury his report for 1881, pp. 1–56; On the Length of a Nautical Mile, Appendix No. 12, pp. 354–356.

HILGARD. Field lever comparator No. 3; reference to, p. 54.

HILL—NAVAL OBSERVATORY. Line run in triangulation of the District of Columbia, p. 24.

HITCHCOCK (steamer). Use of, in Section VIII, p. 35; report on condition of, pp. 64, 65.

HODGKINS, W. C., AID. Services in Section II, p. 16; services in triangulation of the District of Columbia, p. 25.

HOLCOLM HILLS, DENVER. Station, p. 51.

HOLT, DENVER, COLO. Station, p. 51.

HONOLULU, SANDWICH ISLANDS. Tidal observations at pp. 4, 42.

HOOD'S CANAL, W. T., p. 44.

HOOVER, D. N. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

HOSMER, CHARLES, ASSISTANT. Reference to work of, at other points, pp. 10, 14; triangulation of the Mississippi River, p. 35; duty in Coast and Geodetic Survey Office, p. 35.

HUBBARD, MO. Station, pp. 49, 50.

HUDSON RIVER. Topography of shores of, p. 2; reference to, in estimates, p. 5; special operations on the, pp. 15, 21; topography of, p. 15.

HUGHES, E. M., LIEUTENANT, U. S. N. Services in Section III, p. 22; in Section VIII, p. 34; in Section IX, p. 37.

HUGHES, MO. Station, pp. 49, 50.

HUGO. Triangulation station, Colorado, p. 51.

HUMBOLDT HARBOR, SHUMAGINS, p. 45.

HUNTER, MO. Station, pp. 4, 49, 60.

HUTCHINS, C. T., LIEUTENANT, U. S. N. Hydrographic Division, Coast and Geodetic Survey Office, pp. 54, 65.

HYDROGRAPHIC DIVISION, COAST AND GEODETIC SURVEY OFFICE, p. 54; reference to, p. 14; report from, pp. 64–66.

HYDROGRAPHY. Progress of, at various points, pp. 2–4; reference to, in estimates, pp. 5–7; coast of Maine, near Mount Desert, p. 11; of Rockland Harbor, Muscle Ridge Channel, and Skilling's River, Mo., pp. 11, 12; of Pickett's Ledge, entrance to Salem Harbor, Mass., pp. 13, 14;—and topography of the south coast of Long Island, p. 14; of Delaware Bay, p. 18; of the Delaware River, p. 20; below Fort Mifflin, p. 20; north of Chincoteague Inlet, p. 22;—special, in Chesapeake Bay, pp. 22, 23; triangulation, topography, and, of Indian River, Fla., p. 30; of Cape Canaveral shoals and south of the cape, pp. 31, 32; off Egmont Key and Light-House Point, Fla., p. 32; of Mississippi River, p. 34; near Padre Island, coast of Texas, p. 36; of part of California coast, p. 38; of the Columbia River, pp. 42, 43; of Port Discovery and adjacent waters, Strait of Juan de Fuca, W. T., p. 44.

HYPSOMETRY, pp. 26, 27.

I.

IARDELLA, C. T., ASSISTANT. Work on Great South Bay, p. 14; topography of Delaware River from Fort Mifflin to Chester, p. 19.

ICY CAPE, ARCTIC OCEAN, p. 45.

ILLINOIS. Reconnaissance for triangulation in, p. 4; reference to, in estimates, p. 6; triangulation and reconnaissance in, p. 48.

INDEX (GENERAL) OF SCIENTIFIC PAPERS, METHODS, AND RESULTS CONTAINED IN THE APPENDICES TO THE ANNUAL REPORTS OF THE U. S. COAST AND GEODETIC SURVEY, FROM 1845 TO 1880, INCLUSIVE, BY C. H. SINCLAIR, SUBASSISTANT. Appendix No. 6, pp. 91–123.

INDIANA. Primary triangulation in, pp. 4, 46, 47; reference to, in estimates, p. 6; magnetic observations in, p. 47.

INDIANAPOLIS, IND. Magnetic observations at, pp. 4, 47, 48.

INDIAN RIVER. Progress in triangulation and topography of, pp. 3, 30, 31; reference to, in estimates, p. 5; chart of, referred to in estimates, p. 6; sloop Steadfast laid up at, p. 65.

INDIAN RIVER INLET. Reference to, in estimates, p. 6.

INFORMATION FURNISHED FROM THE COAST AND GEODETIC SURVEY OFFICE FROM ORIGINAL SHEETS, TRANSCRIPTS OF RECORDS, ETC., IN REPLY TO SPECIAL CALLS DURING THE YEAR ENDING JUNE 30, 1881. Appendix No. 3, pp. 75–80.

INSTRUMENTS. Terrestrial magnetism; directions for magnetic observations with portable, by C. A. Schott, Assistant. Appendix No. 8, pp. 126–158.

INTENSITY. From observations made by the U. S. Coast and Geodetic Survey between 1833 and 1882. Collection of results for declination, dip, and, by C. A. Schott, Assistant. Appendix No. 9, pp. 159–224.

INTERNAL REVENUE OFFICE. Set of alcoholometers for, p. 53.

IOWA. Magnetic observations in, p. 50.

ISLA GRANDE. Magnetic observations at, p. 38.

ISLE AU HAUT. General chart of, p. 55.

ISLE SAN JOSEF. Magnetic observations at, p. 38.

ISRAEL, Mr., OF LIEUTENANT GREELY'S PARTY TO LADY FRANKLIN BAY, p. 26.

IVERSON'S LANDING. Coast of California, p. 41.

IVY MOUNTAIN, W. VA., p. 28.

J.

JACKSONVILLE, FLA. Reference to, in estimates, p. 6; chart of Saint John's River near, p. 55.

JAMAICA BAY, p. 14.

JAMES RIVER, VA. Chart of, referred to in estimates, p. 6; report on the oyster-beds of the, and of Tangier and Pocomoke Sounds, Md., and Va., by Lieut. Francis Winslow, U. S. N., Assistant, Coast and Geodetic Survey, Appendix No. 11, pp. 269–353.

JAMESTOWN, U. S. STEAMER. Reference to the, p. 45.

JAMESTOWN, DAKOTA. Observations at, pp. 4, 50.

JASPER COUNTY, ILL. Reference to. p. 49.

JENNINGS STATION, TENN., p. 46.

JEPTHA, KY., p. 46.

JOB'S KNOB, W. VA., p. 28.

JOE FLOGGER SHOAL. Detailed survey of, pp. 3, 18.

JOHNS HOPKINS UNIVERSITY, BALTIMORE, MD., p. 3.

JONES INLET, L. I. Tidal observations at, p. 14.

JORDAN RIVER. Hydrography of, pp. 2, 11.

JUNKEN, CHARLES, ASSISTANT. Topography of site for new Naval Observatory in the District of Columbia, p. 25; Drawing Division, Coast and Geodetic Survey Office, p. 63.

JUPITER INLET, FLA. Soundings near, pp. 3, 30.

K.

KADIAK ISLAND, ALASKA. Tidal observations, pp. 4, 45, 61.

KANAWHA FALLS, W. VA., p. 28.

KANSAS. Triangulation across, referred to in estimates, p. 6.

KARCHER, L. Drawing Division, Coast and Geodetic Survey Office, pp. 62, 63.

KASKASKIA RIVER, p. 48.

KATZ, E. M., ENSIGN, U. S. N. Services in Section II, p. 20.

KEATING'S, D. C. Triangulation point, p. 25.

KEENEY MOUNTAIN, W. VA., p. 28.

KENGLEY'S, D. C Triangulation station, pp. 23, 24.

KENTUCKY. Triangulation in, p. 46; referred to in estimates, p. 6.

KEY BISCAYNE BAY. Topography of, referred to in estimates, p. 5.

KEY WEST. Chart from Cape Hatteras to, p. 55; referred to in estimates, p. 6.

KILISUT HARBOR. Survey of, p. 44.

KINCHELOE (Barge). Necessary repairs on, and use of in Section XI, p. 42; report on condition of, p. 65.

KINGSLAND CREEK. Engraving of chart of; referred to in estimates, p. 6.

KLAMATH RIVER. Soundings in, referred to in estimates, p. 7.

KNIGHT, H. M. Engraving Division, Coast and Geodetic Survey Office, p. 64.

KOTZEBUE SOUND, ARCTIC OCEAN, p. 45.

KUMMELL, C. H. Computing Division, Coast and Geodetic Survey Office, pp. 57, 58, 60.

KURO SIWO CURRENT. Reference to in estimates, p. 7.

L.

LADNER'S LANDING, FRASER RIVER, p. 44.

LADY FRANKLIN'S BAY, pp 1, 25, 26, 58.

LAGUNA MADRE, TEX. Topography near, pp. 3, 36.

LAKE BORGNE, LA. Tidal observations at, pp. 3, 34; trigonometrical survey of Mississippi River near, referred to in estimates, p. 5.

LAKE CHAMPLAIN. Triangulation between, and Lake Ontario, pp. 3, 16; referred to in estimates, p. 5; triangulation points on, pp. 13, 17.

LAKE ERIE, p. 47.

LAKE MAUREPAS. Trigonometrical survey of the Mississippi River near, referred to in estimates, p. 5.

LAKE ONTARIO. Triangulation between Lake Champlain and, pp. 3, 16; reference to, in estimates, p. 5.

LAKE PONTCHARTRAIN. Triangulation and survey of the Mississippi River near, referred to in estimates, p. 5.

LAKE PROVIDENCE, LA. Triangulation near, pp. 3, 35.

LAKE RIVER, p. 43.

LAMOINE, VT., p. 10.

LANSINGBURG, N. Y., p. 13.

LA PAZ. Magnetic observations at, p. 38.

LATITUDE OBSERVATIONS, p. 27.

LA UNION, SAN SALVADOR. Magnetic observations at, p. 38.

LAWSON, J. S., ASSISTANT. Operations near Yolo base line, p. 40.

LAZARETTO, DELAWARE RIVER, p. 19.

LEAGUE ISLAND NAVY-YARD, pp. 18, 20.

LEHIGH UNIVERSITY, BETHLEHEM, PA., p. 22.

LEUTZE, E. H. C., LIEUTENANT, U. S. N. Hydrography on special part of California coast, p. 38.

LEWES, DEL. Survey for position of light-house near, pp. 3, 18.

LEWIS COUNTY, N. Y., p. 16.

LEWIS RIVER, p. 43.

LICKING COUNTY, OHIO, p. 47

LIGHT-HOUSE BOARD. Special survey for the, pp. 3, 18.

LIGHT-HOUSE POINT, WEST COAST OF FLORIDA. Hydrography of, pp, 3, 31, 32.

LINCOLN AVENUE, WASHINGTON, D. C., pp. 24, 25.

LINDENKOHL, A. Draughtsman. Drawing Division, Coast and Geodetic Survey Office, p. 62.

LINDENKOHL, H. Drawing Division, Coast and Geodetic Survey Office, p. 62.

LIPPINCOTT. Old trigonometrical station on the Delaware, not found, p. 21.

LISY ISLAND, COAST OF ALASKA, p. 45,

LITTLE RIVER INLET. Chart of, referred to in estimates, p. 6.

LITTLE TINNICUM ISLAND. Hydrography of Delaware River from upper end of, pp. 3, 20: changes on, and at either end of, p. 19.

LONDON, ENGLAND, p. 30.

LONE MOUNTAIN, NEV., p, 50.

LONG BAY. Chart of, referred to in estimates, p. 6.

LONG BEACH, p. 14; drawing of chart of, referred to in estimates, p. 6.

LONGFELLOW, A. W., ASSISTANT. Topography of Frenchman's Bay, Me., p. 10.

LONG ISLAND. Hydrography and topography of coast of, pp. 2, 14; reference to in estimates, p. 5; examination of inland waters between, and Cape Charles, Va., pp. 3, 22.

LONGITUDE OBSERVATIONS AT CAPE MAY, N. J., p. 17; telegraphic, p. 27.

LORETO. Magnetic observations at, p. 38.

LOS ANGELES, CAL. Triangulation and topography of, referred to in estimates, p. 7.

LOUISIANA. Hydrography and topography of coast of, referred to in estimates, p. 5.

LOUISVILLE, KY. Base line, pp. 4, 17, 46; astronomical observations at, p. 46.

LOWER CALIFORNIA. Magnetic observations in, pp. 3, 37.

LOWER HOOD'S CANAL, p. 44.

LULL, E. P., COMMANDER, U. S. N. Hydrographic Inspector, Coast and Geodetic Survey Office; hydrography north of Chincoteague Inlet, p. 22: relieved from duty in Hydrographic Division, pp. 54, 65.

M.

MACHIAS BAY. Chart of; reference to in estimates, p. 6.

MACHOTANK CREEK, MD., p. 23.

MACKINAC, MICH, Magnetic observations at, pp. 4, 47.

MADEIRA ISLAND. Reference to Columbus' first voyage to America, p, 58.

MADISON, WIS. Observations at, p. 4; computation of, p. 60.

MADISON OBSERVATORY, WIS., pp. 49, 58, 60.

MAEDEL, E. A. Engraving Division, Coast and Geodetic Survey Office, p. 64.

MAGDALENA BAY. Magnetic observations at, p. 38.

MAGNETIC OBSERVATIONS. In Alaska, p. 4; in Ohio, p. 4; throughout the States, reference to, in estimates, pp. 5, 6; in North Wisconsin, Minnesota, and Dakota, p. 27; coasts of Lower California, Mexico, and Central America, pp. 37, 38; in Ohio, Michigan, Indiana, and Wisconsin, p. 47; at Madison Observatory, Wisconsin, p. 49; in Minnesota, Dakota, Nebraska, and Iowa, p. 50; computation of, p. 59.

MAGNETIC OBSERVATORY. Madison, Wis., pp. 4, 58; at Washington, D. C.. pp. 25, 26.

MAGNETIC SURVEY OF THE UNITED STATES. Remarks on, p. 1; reference to, in estimates, p. 7.

MAGNETISM (Terrestrial). Collection of results for declination, dip, and intensity, from observations made by the U. S. Coast and Geodetic Survey between 1833 and 1882, by C. A. Schott, Assistant. Appendix No. 9, pp. 159–224.

MAGNOLIA AVENUE, WASHINGTON, D. C., p. 25.

MAIDEN'S ISLAND, DELAWARE RIVER. Changes in, p. 19.

MAIN, J. Computing Division, Coast and Geodetic Survey Office, p. 58; resignation, owing to ill health, p. 57.

MAINE. Topography of, p. 10; referred to in estimates, p. 5; tidal observations off coast of, p. 11.

MAINE, GULF OF. Tidal and current observations in the, referred to in estimates, p. 5.

MANSFIELD, H. B., LIEUTENANT, U. S. N. Hydrography of Delaware River, p. 20; services in Hydrographic Division, Coast and Geodetic Survey Office, p. 65.

MANZANILLA. Magnetic observations at, p. 38.

MARCUS HOOK, DELAWARE RIVER, pp. 3, 19, 20.

MARINDIN, H. L., ASSISTANT. Hydrography below Fort Mifflin, Delaware River, p. 20.

MARION, VA. Magnetic observations at, pp. 3, 27.

MARR, R. A., AID. Services in Section XVI, p. 51.

MARTINEZ. Station, p. 40.

MARYLAND. Hydrography of coast of, pp. 3, 22; to connect coast triangulation near boundary of, and Virginia, p. 27; referred to in estimates, p. 5; hypsometrical map of, pp. 26, 27.

MARYLAND FISH COMMISSION. Reference to annual report of, p. 2.

MARYSVILLE BUTTE, p. 39.

MASON, DAVID. Magnetic observations at Madison Observatory, Wis., p. 49; resignation noted, p. 58.

MAYO, HENRY T., ENSIGN, U. S. N. Services in Section XI, p. 44.

MAZATLAN, MEX. Tidal observations at, pp. 4, 38, 61; magnetic observations at, p. 38.

McARTHUR (steamer). Use of, in Section X, p. 38; reference to, p. 64.

McCARLIN, IND. Station, p. 47.

McCORKLE, S. C. Reconnaissance west of Lake Champlain, p. 16; triangulation of Delaware River, pp. 18, 19; triangulation of the District of Columbia, pp. 23, 24, 59; on duty in Coast and Geodetic Survey Office, pp. 52, 53.

McCRIE'S SHOAL, NEAR LEWES, DEL. Change of position of, noted, p. 18.

McDONNELL, THOMAS. In charge of chart room of Coast and Geodetic Survey Office, p. 55.

McGRATH, JOHN. Services in Section XVI, p. 51; in Computing Division, Coast and Geodetic Survey Office, pp. 57, 59, 60.

MEIGS, JOHN C. (snag-boat). Use of, in Section VIII, p. 36.

MEMPHIS, TENN. Triangulation near, p. 32; reference to, in estimates, p. 5.

MENDOCINO CITY. Chart of coast near, referred to in estimates, p. 7.

MENDOCINO COUNTY, CAL., p. 41.

MENTZ, G. W., MASTER, U. S. N. Services in Section VI, p. 30.

MERRIMAN, PROFESSOR MANSFIELD, OF LEHIGH UNIVERSITY, PA. Reference to, p. 22.

METEOROLOGICAL RESEARCHES. For the Coast Pilot, p. 2; Part III; barometric hypsometry and reduction of the barometer to sea-level, by Wm. Ferrel. Appendix No. 10, pp. 225–268.

METHOD OF OBSERVING THE COINCIDENCE OF VIBRATIONS OF TWO PENDULUMS. By Assistant C. S. Peirce, Appendix No. 16, pp. 457–460.

MEXICO. Magnetic observations along coast of, p. 37.

MEXICO, GULF OF. Development of, p. 1; astronomical and magnetic observations throughout the, reference to, in estimates, p. 5; chart of, referred to in estimates, p. 6; natural walls of sand formed on parts of shore of, p. 10; tidal observations in, not resumed, p. 61; model of, from recent deep-sea soundings, p. 62.

MICHIGAN. Magnetic observations in, p. 47.

MILE, NAUTICAL. On the length of, by Professor J. E. Hilgard, Appendix No. 12, pp. 354–356.

MILK HOUSE ROAD, D. C., p. 23.

MILL CREEK REACH, PENOBSCOT RIVER, ME. Location of a buoy, pp. 2, 11.

MILLIKEN'S BEND, LA., p. 32.

MINNESOTA. Magnetic observations in, pp. 27, 50.

MISCELLANEOUS DIVISION, COAST AND GEODETIC SURVEY OFFICE, pp. 54, 55.

MISSISSIPPI DELTA. Reference to, in estimates, p. 5.

MISSISSIPPI RIVER. Hydrography of, pp. 3, 34; triangulation of, pp. 3, 34–36; reference to, in estimates, p. 5; survey, pp. 32, 33.

MISSISSIPPI RIVER COMMISSION, pp. 32, 34; self-regulating tide-gauge furnished, p. 61.

MISSOURI. Primary triangulation in, pp. 4, 49; referred to in estimates, p. 6.

MITCHELL, HENRY, ASSISTANT. New rule for tides in Delaware Bay, by, Appendix No. 18, pp. 464–469.

MOBILE BAY. Chart of entrance to, referred to in estimates, p. 6.

MOHAWK RIVER, p. 16.

MOLKOW, E. Drawing Division, Coast and Geodetic Survey Office, p. 63.

MONAHON, H. T., LIEUTENANT, U. S. N. Services in Section I, pp. 11, 14.

MONTANA STATION, N. J., p. 21.

MONTAUK POINT, L. I., pp. 3, 22.

MONTEREY. Magnetic observations at, p. 38.

MONTEREY BAY, CAL. Triangulation near, referred to in estimates, p. 7.

MONTICELLO STATION, p. 39.

MONTREAL, CANADA, p. 17.

MOORE, E. K., LIEUTENANT, U. S. N. Services in Section X, p. 38.

MOORE, FRANK. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

MOOS À BEC REACH. Reference to, in estimates, p. 5.

MORRELL, HENRY, MASTER, U. S. N. Services in Section VI, p. 30.

MORRISON, GEORGE A. Coast Pilot work, p. 22.

MONROE COUNTY, OHIO, p. 47.

MORSE, FREMONT, AID. Services in Section X, pp. 41, 42.

MOSMAN, A. T., ASSISTANT. Triangulation in West Virginia, pp. 27, 28.

MOSQUITO INLET. Chart of, referred to in estimates, p. 6.

MOSQUITO LAGOON. Referred to in estimates, p. 6.

MOUNTAIN TOP, KY., p. 4.

MOUNT CALLAHAN, NEV., p. 50.

MOUNT DESERT. Hydrography of coast of Maine near, p. 11.

MOUNT DIABLO, pp. 39, 40.

MOUNT HELENA, p. 39.

MOUNT HOLLY, N. J. Station recovered and remarked, p. 21.

MOUNT LOOKOUT, OHIO, p. 47.

MOUNT LORE, TENN., p. 46.

MOUNT MANSFIELD, VT. Triangulation station, pp. 12, 17.

MOUNT MONADNOCK, p. 13.

MOUNT OLIVE STATION, N. J., p. 21.
MOUNT PLEASANT AVENUE, WASHINGTON, D. C., p. 25.
MOUNT TOM, p. 13.
MOUNT WASHINGTON, N. H., p. 2; geodetic station on, p. 12.
MURDOCK LANDING, COAST OF TEXAS, p. 36.
MUSCLE RIDGE CHANNEL, ME. Soundings in, pp. 2, 11.
MUSKINGUM RIVER, OHIO, p. 47.

N.

NANTUCKET. Chart of coast from, to Cape Hatteras; reference to in estimates, p. 6; deep-sea soundings near, p. 29.
NANTUCKET AND PAMPLICO-CHESAPEAKE, arcs of the meridian, p. 58.
NASHVILLE, TENN. Astronomical observations from Capitol building at, pp. 46, 47.
NATCHEZ, MISS. Organization of triangulation party at, by Assistant Dennis. p. 34; steamer Barataria laid up at, p. 35.
NAUTICAL MILE. On the length of a, by Prof. J. E. Hilgard, Appendix No. 12, pp. 354–356.
NAVAL OBSERVATORY. Survey of site for new, p. 3; topography of site for new, p. 25.
NAVAL OBSERVATORY (old). Instruments placed in position at, p. 17; base in triangulation of the District, p. 24.
NAVY DEPARTMENT. Officers and men detailed by, for duty on Coast and Geodetic Survey, p. 65.
NEBRASKA. Magnetic observations in, p. 50.
NEVADA. Triangulation in, pp. 4, 50; referred to in estimates, p. 7; magnetic observations in, p. 50.
NEWBURG, N. Y. Triangulation of the Hudson near, p. 15.
NEW CASTLE. Triangulation of Delaware River near, pp. 3, 20.
NEWCOMB, PROF. SIMON. Experiments on velocity of light by, p. 24.
NEW ENGLAND COAST, p. 10.
NEW FIVE-METER PRIMARY BASE APPARATUS, AS DESIGNED BY ASSISTANT SCHOTT. Reference to, p. 51, 52.
NEW HAMPSHIRE. Triangulation in, pp. 2, 12; referred to in estimates, p. 5.
NEW HARMONY, IND. Magnetic observations at, pp. 4, 47.
NEW INLET, L. I., p. 14.
NEW JERSEY. Topography of shores of, p. 3; triangulation of, pp. 3, 21; reference to, in estimates, p. 5; reference to shore of, p. 19.
NEW JERSEY SOUTHERN RAILROAD, SANDY HOOK. Tide-gauge at depot of, p. 15.
NEW ORLEANS, LA. Trigonometrical survey of Mississippi River near, p. 57; reference to, in estimates, p. 5; the Gedney docked for repairs at, p. 36; telegraphic of longitude, uniting Greenwich, England, and, p. 58.
NEWPORT, LOS ANGELES, COUNTY, CAL. Coast triangulation and topography near, reference to, in estimates, p. 7.
NEWPORT, R. I. Deep-sea soundings off, pp. 29, 30.
NEW RULE FOR TIDES IN DELAWARE BAY. By Assistant Henry Mitchell, Appendix No. 18, pp. 464–469.
NEW WESTMINSTER, B. C., p. 44.
NEW YORK (State). Geodetic operations and reconnaisance in, pp. 2, 3, 12, 13; position of lights between coast of, on the Rio Grande, reference to, in estimates, p. 6; reference to survey of, by State authorities, p. 16; primary triangulation in, pp. 16, 17.
NEW YORK CITY. From, to Chesapeake Bay for the Coast Pilot. p. 2; position of new light-houses between Eastport, Me., and; reference to, in estimates, p. 5.
NEW YORK HARBOR. Surveys of; reference to, in estimates, p. 5.
NICHOLS, H. E., LIEUTENANT-COMMANDER, U. S. N. Magnetic observations along coasts of California, Mexico, and Central America, pp. 37, 38.
NICKELS, J. A. H., LIEUTENANT, U. S. N. Services in Section VI, p. 31; in Section VII, p. 32.
NISSEN, H. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.
NORTH BASE, MO., p. 49.
NORTH CAROLINA. Closing of triangulation from Blue Ridge to junction line in, p. 28.
NORTHEAST MOUNTAIN, VT., pp. 2, 12.
NORTHERN KENTUCKY, p. 4.
NORTHERN WISCONSIN, p. 27.
NORTH GREENLAND. Reference to expedition to, p. 25.
NORTH HAVEN, PENOBSCOT BAY, ME. Tidal and meteorological observations at, pp. 2, 11, 61.
NORTH MOUNTAIN, MD., p. 27.
NORTH MOUNTAIN RANGE, MD., p. 27.
NORTH WEST HARBOR. Shumagins, p. 45.
NORTHWEST YOLO BASE LINE STATIONS, p. 40.
NOSTRAND, WARNER H., ENSIGN U. S. N. Services in Section I, pp. 1, 11, 12, 14.
NOTICES TO MARINERS. Preparation of, p. 65.

O.

OAK BAY, W. T. Survey of, p. 44.
OBITUARY NOTICES. Prof. Benjamin Peirce, late consulting geometer of the Coast and Geodetic Survey, pp. 8, 9; A. M. Harrison, late Assistant Coast and Geodetic Survey, p 9; C. L. Drinkard, late clerk in office of the Assistant in charge, pp. 55, 56, 64.
OBSERVATIONS. Pendulum, pp. 1, 26; see also Appendices Nos. 14, 15, 16, pp. .
OBSERVATIONS. Tidal, p. 61; office work in Tidal Division, pp. 61, 62.
OBSERVATORY. Madison, Wis., pp. 49, 58.
OBSERVATORY. New Naval, topographical survey of site for, pp. 3, 25.
OBSERVATORY (old), NAVAL, p. 3; longitude instruments placed in, p. 17; station in triangulation of the D. C., pp. 23, 24.
OCRACOKE INLET. Chart of Atlantic coast from, to Cape Fear, reference to, in estimates, p. 6.
OFFICE REPORTS, pp. 57–66.
OFFICE WORK OF THE U. S. COAST AND GEODETIC SURVEY FOR THE YEAR ENDING DECEMBER 31, 1880. Statistics of field and, Appendix No. 2, pp. 73, 74.
OFFICE WORK. Enumeration of, pp. 2–4; referred to in estimates for Atlantic and Gulf coasts, p. 6; estimates for expenses of Pacific coast, p. 7; in Tidal Division, pp. 61, 62; of Hydrographic Division, pp. 65, 66.
OGDEN, H. G., ASSISTANT. Topography of Dyer's Neck and Petit Manan Point, coast of Maine, p. 10; assigned to charge of Engraving Division, p. 10; reference to accuracy of work, p. 34; report from Engraving Division by, pp. 63, 64.
OHIO. Reconnaissance for extension of primary triangulation across, pp. 4, 47; reference to, in estimates, p. 6; magnetic observations in, pp. 4, 47.
OHIO RIVER. Triangulation extended to, p. 3.
OLD COAST SURVEY OFFICE, p. 24.
OLD GREENVILLE LANDING, MISS., p. 35.
OLD MAN'S CREEK, DELAWARE RIVER, p. 20.
OLYMPIA, WASH. TER., p. 44.
OMAHA, NEB. Magnetic observations in, pp. 4, 50.
ON A METHOD OF READILY TRANSFERRING THE UNDERGROUND MARK AT A BASE MONUMENT. By Assistant O. H. Tittmann, Appendix No. 13, pp. 357, 358.
ON A METHOD OF OBSERVING THE COINCIDENCE OF VIBRATIONS OF TWO PENDULUMS. By Assistant C. S. Peirce, Appendix No. 16, pp. 457–460.
ONANCOOK CREEK, MD. Oyster beds of, p. 23.
ONEIDA COUNTY, N. Y., p. 16.
ON THE DEDUCTION OF THE ELLIPTICITY OF THE EARTH FROM PENDULUM EXPERIMENTS. By Assistant C. S. Peirce, Appendix No. 15, pp. 441–456.
ON THE FLEXURE OF PENDULUM SUPPORTS. By Assistant C. S. Peirce, Appendix No. 14, pp. 359–441.
ON THE LENGTH OF A NAUTICAL MILE. By Prof. J. E. Hilgard, Appendix No. 12, pp. 354–356.
ON THE VALUE OF GRAVITY, AT PARIS. By Assistant C. S. Peirce, Appendix No. 17, pp. 461–463.
ONTONAGON, MICH. Magnetic observations at, pp. 4, 47.
ORDNANCE OFFICE U. S. WAR DEPARTMENT. Gauges compared for, p. 53.
OREGON. Coast Pilot of, referred to in estimates, p. 7; new edition of, prepared by Assistant George Davidson, p. 2; off-shore soundings coast of, reference to, in estimates, p. 7.
OSTERHAUS, HUGO, LIEUTENANT, U. S. N. Services in Section II, pp. 18, 20.
OSTRICH BAY, PORT ORCHARD, p. 43.
O'SULLIVAN, T. J. Drawing Division, Coast and Geodetic Survey Office, p. 63.
OTSEGO GEODETIC STATION. Observations at, p. 16; Otsego Rafinesque, p. 16.

OUIJANO, MR. FIACRO. Tidal observations at Mazatlan, Mex., p. 38.

OVER, FRANK. Electrotyping and Photographing Division, Coast and Geodetic Survey Office, p. 54.

OYSTER BEDS. Survey of, pp. 2, 3; use of the Palinurus in examination of oyster beds of Chesapeake Bay, p. 22; special hydrography in connection with, pp. 22, 23; report on the, beds of the James River, Va., and of Tangier and Pocomoke Sounds, Md., and Va., by Lieut. Francis Winslow, U. S.N., Assistant Coast and Geodetic Survey, Appendix No. 11, pp. 269–353.

P.

PACIFIC COAST. Progress of work on the, pp. 1, 3, 4; triangulation along 39th parallel of latitude to connect Atlantic and, pp. 1, 50; reference to, in estimates, pp. 6, 7; observations for latitude and longitude on, referred to in estimates, p. 7; field and office work on, and tidal observations, reference in estimates, p. 7. Coast Pilot for the, pp. 2, 63; referred to in estimates, p. 7; line of geodetic levels, estimated for, p. 7; abstracts of work on, geographical arrangement, p. 10; report for the Board of Engineers of the, of harbors of refuge on that coast, p. 40; record of tides at Sandwich Islands comparable with those made on, p. 42; tide tables for 1882.

PACIFIC COASTS, AND INTERIOR OF THE UNITED STATES, DURING THE YEAR ENDING JUNE 30, 1881. Distribution of surveying parties upon the Atlantic, Gulf of Mexico, and, Appendix No. 1. pp. 67–72.

PADRE ISLAND. Hydrography of coast of Texas off, pp. 3, 36.

PAH-RAH. Station, p. 50.

PALINURUS (schooner). Use of, in survey of oyster beds in Chesapeake Bay, p. 2; use of, in Section III, p. 22.

PARIS. On the value of gravity at, by Prof. C. S. Peirce, Appendix No. 17, pp. 461–463.

PARKERSBURG, W. VA. Magnetic observations at, pp. 3, 27.

PARKINSON SIGNAL, ILL., p. 48.

PARK'S TRIANGULATION POINT, p. 30.

PARR'S RIDGE, p. 27.

PARSONS, F. H., AID. Services in Section II, p. 17: in Section XIV, p. 47; services in office of Superintendent of Coast and Geodetic Survey, pp. 53, 54; Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.

PATTERSON, C. P., LL.D., LATE SUPERINTENDENT OF U. S. COAST AND GEODETIC SURVEY. Reference to his death, p. 1; intention to submit estimates for certain class of vessels for the Coast Survey service, p. 65.

PEARY, R. E. Drawing Division, Coast and Geodetic Survey Office, p. 63.

PEIRCE, PROF. BENJAMIN, LATE CONSULTING GEOMETER OF COAST AND GEODETIC SURVEY. Obituary of, pp. 8, 9.

PEIRCE, C. S., ASSISTANT. Pendulum observations, p. 26; on the flexure of pendulum supports, by, Appendix No. 14, pp. 359–441; on the deduction of the ellipticity of the earth from pendulum experiments, by, Appendix No. 15, pp. 442–456; on a method of observing the coincidence of vibrations of two pendulums, by, Appendix No 16, pp. 457–460; on the value of gravity, at Paris, by, Appendix No. 17, pp. 461–463.

PEMBINA, DAK. Magnetic observations at, pp. 4, 50.

PENDULUM EXPERIMENTS. On the deduction of the ellipticity of the earth from, by Assistant C. S. Peirce, Appendix No. 15, pp. 442–456.

PENDULUM OBSERVATIONS, p. 26.

PENDULUM SUPPORTS. On the flexure of, by Assistant C. S. Peirce, Appendix No. 14, pp. 359–441.

PENDULUMS. On a method of observing the coincidence of vibrations of two, by Assistant C. S. Peirce, Appendix No. 16, pp. 457–460.

PEN MOUNT, N. Y., p. 16.

PENN'S GROVE, N. J. Triangulation near, pp. 3, 20.

PENNSYLVANIA. Triangulation in, pp. 3, 21, 22; reference to, in estimates, p. 5; triangulation of, on shores of Delaware River, p. 19.

PENOBSCOT BAY. Tidal and meteorological observations in, p. 2.

PENOBSCOT RIVER. Hydrography of, pp. 2, 11.

PENSACOLA (entrance). Chart of, reference to, in estimates, p. 6.

PEQUEÑA BAY. Magnetic observations at, p. 38.

PERKINS, F. W., ASSISTANT. Triangulation and reconnaissance in Illinois, p. 48; in office of the superintendent, p. 53.

PERMANENT TRIAL BASE AT FORT MEYER, D. C., p. 26.

PERSONNEL. Of the Hydrographic Division, Coast and Geodetic Survey Office, p. 65.

PERUVIAN ARC, p. 58.

PETERSEN, A. Engraving Division, Coast and Geodetic Survey Office, p. 64.

PETIT MANAN. Progress of topography near, pp. 2, 10; reference to, in estimates, p. 5.

PHILADELPHIA. Remarking of triangulation points in the vicinity of, p. 15; shoal spot reported off port of, not found, p. 18; organization of party at, for triangulation of the Delaware River, p. 20. Repairs on the "Ready" at, p. 21.

PHILIPP'S POINT. Magnetic observations at, p. 38.

PHOTOGRAPHING DIVISION. Electrotyping and, of Coast and Geodetic Survey Office, p. 54.

PHOTOLITHOGRAPHY. Maps prepared in Drawing Division of Coast and Geodetic Survey Office for, p. 63.

PICHILINQUE BAY. Magnetic observations, p. 38.

PICKETT'S LEDGE. Entrance to Salem Harbor, Mass; development of, p. 2; hydrography of, p. 13.

PIGEON HILL, ME , p. 10.

PIGEON HILL BAY. Remarkable natural sea-wall found on shore of, p. 10.

PINE HILL, CAL., p 39.

PINE HILL, N. J., p. 21.

PLANE TABLE. Preparation of history of, by late A. M. Harrison, Assistant, p. 9.

PLAQUEMINE. Hydrography of the Mississippi River to, pp. 3, 32, 34.

PLATES COMPLETED, CONTINUED, OR COMMENCED DURING THE YEAR ENDING JUNE 30, 1881. Engraving Division, Appendix No. 5, pp. 84–90.

PLEASANT BAY. Chart of, referred to in estimates, p. 6.

PLOVER BAY. Eastern Siberia, pp. 45, 46.

POCOMOKE SOUNDS, MD., AND VA. Report on the oyster beds of the James River, Va., and of Tangier and, by Lieut. Francis Winslow, U S. N., Assistant, Coast and Geodetic Survey, Appendix No. 11, pp. 269–353.

POINT ABREEJOS. Magnetic observations, p. 38.

POINT ARENA, CAL. Triangulation and topography near, pp. 4, 41; referred to in estimates, p. 7; chart of, reference to, in estimates, p. 7; site for proposed light-house near, p. 42.

POINT ARGUELLO, CAL. Hydrography of coast near, pp. 4, 38.

POINT BARROW, ARCTIC OCEAN. Reference to expedition sent to, pp. 1, 25, 41, 45, 58.

POINT BUCHON. Topography near, pp. 38, 39.

POINT CABALLO. Topography near, p. 38.

POINT CONCEPTION. Triangulation near and chart of, reference to, in estimates, p 7.

POINT COUPÉE, LA. Lines of level near, pp. 3, 33, 35.

POINT IGNATIO. Magnetic observations at, p. 38.

POINT ORFORD. Soundings near, reference to, in estimates, p. 7.

POINT PINOS. Chart of, referred to in estimates, p. 7.

POINT REYES. Chart of coast near, reference to, in estimates, p. 7; sight for proposed light-house near p. 42.

"POINT ROAD," N. Y., p. 15.

POINT SAL, CAL. Hydrography near, pp. 4, 38.

POINT SAN FELIPE. Magnetic observations at, p. 38.

POINT VINCENTE. Chart of coast near, referred to in estimates, p. 7.

POLAR EXPEDITIONS. Magnetic observers of the, instructed at Magnetic Observatory, Washington, p. 25.

POND, CHARLES F., ENSIGN, U. S. N. Services in Section X, p. 38.

PONGOTEAGUE CREEK, p. 23.

PORT ALTHORP, CROSS SOUND, p. 45.

PORT BELCHER, ARCTIC OCEAN, p. 45.

PORT CLARENCE, BERING STRAIT, p. 46.

PORT DISCOVERY. Hydrography of, pp. 4, 44.

PORTER, DR. J. G. Computing Division, Coast and Geodetic Survey Office, p. 59.

PORT ESCONDIDO. Magnetic observations at, p. 38.

PORT HARFORD, p. 39.

PORT HUDSON, MISSISSIPPI RIVER, p. 34.

PORT MULGRAVE, p. 45.

PORT ORCHARD, WASH. TER. Topography of, pp. 4, 43, 44.

PORT PENN, DELAWARE RIVER. Reference to, in estimates, p. 6.

PORTSMOUTH HARBOR. Survey of, referred to in estimates, p. 5.

POTATO HILL, VT. Observations at, pp. 2, 12, 13.

POTOMAC RIVER. Plane table survey of, reference to, in estimates, p. 5; reference to mean high water of the, p. 25.

POWDER MAGAZINE, DELAWARE RIVER, p. 20.

POWELL, J. W. Chief of the U. S. Geological Survey, p. 59.

PRATT, J. F., SUBASSISTANT. Services in Section X, pp. 39, 40.

PRESIDIO. Station at San Francisco, p. 37; magnetic observations at, p. 38.

PRESTON, E. D. Special office duty, p. 54.

PRIBILOFF GROUP, p. 45.

PRIMARY TRIANGULATION. In Vermont, p. 12; in New York, pp. 16, 17; of California coast, p. 39; stations at ends of Yolo Base-line, pp. 39, 40; in Missouri, p. 49; eastward along 39th parallel in Nevada, and magnetic observations, p. 50; eastward from the El Paso base, p. 51.

PROSPECT HARBOR. Chart of, referred to in estimates, p. 6.

PROSPECT-HELDERBERG. Triangulation station, p. 16.

PROSPECT-MARCY STATIONS, p. 16.

PROSPECT MOUNTAIN, N. Y., pp. 12, 17.

PROSPECT STATION, KY., p. 46.

PROVIDENCE, LA. Triangulation of the Mississippi River from, pp. 3, 32.

PROVIDENCE, R. I. Tidal observations at, pp. 14, 61; the Blake repaired and laid up at, pp. 29, 30.

PUGET SOUND. Topography and hodrography, pp. 4, 43; reference to, in estimates, p. 7.

PUTAH CREEK, CAL., p. 40.

PUTNAM, CHARLES T., U. S. N. Services in Section X, p. 38.

Q.

QUEEN'S CHAPEL (road). Reference to, in triangulation of the District of Columbia, p. 25.

QUICK (schooner). Use of the, in report, p. 65.

QUIMBY, PROF. E. T. Triangulation of New Hampshire, p. 12.

QUODDY HEAD. Chart of Atlantic coast from Cape Cod to, reference to, in estimates, p. 6.

R.

RACCOON ISLAND. Triangulation and topography of, pp. 3, 19, 20.

RAPPAHANNOCK RIVER. Examination of oyster beds in, p. 23.

RAY, HENRY P., LIEUTENANT, U. S. A. Charge of expedition to the Arctic regions, pp. 1, 41.

READY (schooner). Use of, in Section II, pp. 20–22.

RECONNAISSANCE. In Kentucky, pp. 4, 46; in Ohio, pp. 4, 47; in Indiana, pp. 4, 47; in Illinois, pp. 4, 48; in Vermont, p. 12; west from Lake Champlain, p. 16; in British Columbia, p. 44.

RED RIVER LANDING, p. 33.

REFORM SCHOOL. Point in triangulation of the District, p. 24.

REICH, HENRY F., MASTER, U. S. N. Services in Section VI, p. 31.

REILLY, J. S. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

REPAIRS AND EQUIPMENT OF VESSELS, pp. 64, 65.

REPORTS OF THE UNITED STATES COAST AND GEODETIC SURVEY FROM 1845 TO 1880, INCLUSIVE. General Index of scientific papers, methods, and results contained in the Appendices to, by C. H. Sinclair, Sub-Assistant, Appendix No. 6, pp. 91–123.

REPORTS. Office, Computing Division, pp. 57–60; Tidal Division, pp. 61, 62; Drawing Division, pp. 62, 63; Engraving Division, pp. 63, 64; Hydrographic Division, pp. 64–66.

RESEARCH (schooner). Use of, in Section VIII, pp. 34, 65.

RESEARCHES (meteorological). Part III. Barometric hypsometry and reduction of the barometer to sea-level. William Ferrel, Appendix No. 10, pp. 225–268.

RESUMÉ OF LEVELING OPERATIONS ON MISSISSIPPI RIVER, pp. 32, 33.

REYNOLDS, E. L., ENSIGN, U. S. N. Services in Section VI, p. 30.

RICHLAND COUNTY, OHIO, p. 47.

RICHMOND, IND. Magnetic observations at, pp. 4, 47.

RIDLEY CREEK, p. 19.

RIGGS ROAD, D. C., p. 25.

RILEY, KY. Triangulation point, pp. 4, 46.

RILEY-MOUNTAIN TOP. Line found to be impracticable, p. 46.

RIO GRANDE. Hydrography of coast of Texas near, referred to in estimates, p. 5; to continue the determination of the positions of new light-houses and life-saving stations, referred to in estimates, p. 6.

ROAD STREET, GEORGETOWN, D. C., p. 25.

ROBINSON'S LANDING, CAL., p. 41.

ROCK CREEK, p. 25.

ROCK CREEK CHURCH ROAD, D. C., p. 25.

ROCKLAND HARBOR, ME. Hydrographic survey of, pp. 2, 11.

ROCKWELL, CLEVELAND, ASSISTANT. Topography, triangulation, and hydrography of Columbia River, pp. 42, 43.

RODGERS, A. F., ASSISTANT. Primary triangulation on California coast, pp. 39, 40.

RODNEY, MISS. Lines of leveling, pp. 3, 32, 33.

ROSE, WALDEMAN D., ENSIGN, U. S. N. Services in Section X, p. 38.

RULE (NEW) FOR TIDES IN DELAWARE BAY, ASSISTANT HENRY MITCHELL. Appendix No. 18, pp. 464–469.

RUMPF, GOTLIEB, COMPUTING DIVISION, COAST AND GEODETIC SURVEY OFFICE, pp. 58, 59.

RUSSIA. Determination of longitude of meridian separating the American possessions from those of, p. 46.

RUSSIAN RIVER, CAL. Dangers to navigation north of, p. 42.

S.

SABINE PASS. Triangulation and magnetic observations at, reference to, in estimates, p. 5.

SACRAMENTO VALLEY, p. 39.

SAEGMULLER, G. N., CHIEF MECHANICIAN. Improvements in instrumental appliances devised by, p. 52; in charge of instrument shop of Coast and Geodetic Survey Office, p. 55.

SAGADAHOCK (steam-launch). Use of, in Section I, p. 11; relative to, p. 64.

SAINT ANDREW'S BAY. Chart of, referred to in estimates, p. 6.

SAINT CROIX RIVER. Referred to in estimates, p. 5.

SAINT GEORGE'S SOUND, FLA. Soundings off, p. 3.

SAINT HELEN'S, COLUMBIA RIVER, pp. 4, 42, 43.

SAINT JOHN'S RIVER, FLA. Hydrography of, referred to in estimates, p. 5. Chart of, referred to in estimates, p. 6.

SAINT JOSEPH'S, LA. Leveling work near, p. 35.

SAINT JOSEPH'S BAY. Chart of, referred to in estimates, p. 6.

SAINT LAWRENCE ISLAND, PLOVER BAY, p. 46.

SAINT LAWRENCE RIVER. Extension of primary triangulation north to, p. 16.

SAINT MATTHEW ISLAND, PLOVER BAY, p. 46.

SAINT PAUL ISLAND, PRIBILOFF GROUP, p. 45.

SAINT PAUL'S, KADIAK ISLAND, ALASKA. Tidal observations at, pp. 4, 45.

SALEM, MASS. Development of ledge at entrance to harbor, pp. 2, 13.

SALINA CRUZ. Magnetic observations at, p. 38.

SALT LAKE CITY, UTAH, p. 50.

SALT POINT, CAL., p. 42.

SALT RIVER, KY., p. 4.

SAN BLAS. Magnetic observations at, p. 38.

SAN DIEGO, CAL. Reference to, in estimates, p. 7; magnetic observations at, p. 38.

SANDWICH ISLANDS. Tidal observations, pp. 4, 42, 61.

SANDY HOOK, N. Y. Tide gauge at, pp. 2, 15, 61; chart of, referred to in estimates, p. 6.

SAN FRANCISCO, CAL. Tidal observations at, pp. 39, 40; referred to in estimates, p. 7; arrival of the Hassler at, p. 38; departure of expedition to Arctic regions from, p. 41; and return to, p. 46; magnetic observations and geodetic operations between, and Salt Lake City, p. 50.

SAN FRANCISCO BAY, CAL. Tide gauge inside, pp. 4, 39; to develop hydrographic changes in, reference to, in estimates, p. 7.

SAN GERONIMO. Magnetic observations, p. 38.

SANHEDRIN STATION, CAL. pp. 4, 39.

SAN JOSÉ DEL CABO. Magnetic observations, p. 38.

SAN LUIS GONZALES BAY. Magnetic observations, p. 38.

SAN LUIS OBISPO. Topography of coast near, pp. 4, 38; chart o coast near, reference to, in estimates, p. 7; magnetic observations at, p. 38.
SAN MARTIN ISLAND. Magnetic observations, p. 38.
SAN PEDRO. Reference to, in estimates, p. 7; magnetic observations at, p. 38.
SAN SALVADOR. Magnetic observations in, p. 38.
SANTA BARBARA. Magnetic observations at, p. 38; the McArthur laid up at, p. 38.
SANTA BARBARA BAY. Magnetic observations in, p. 38.
SANTA MARIA COVE. Magnetic observations at, p. 38.
SANTA TERESA BAY. Magnetic observations in, p. 38.
SAUCELITO, CAL. Tide gauges at, pp. 4, 39, 61.
SAULT STE. MARIE, MICH. Magnetic observations at, pp. 4, 47.
SAUNDER'S LANDING, CAL., p. 41.
SAVANNAH, GA., p. 30.
SAWYER, FRANK E., MASTER, U. S. N. Services in Section I, pp. 11, 14.
SCAPOOSA BAY, p. 43.
SCHENK, C. Reconnaissance in Kentucky, p. 46.
SCHNACKENBERG STATION, p. 50.
SCHOTT, C. A., ASSISTANT. Chief of Computing Division, p. 17; statement in regard to closing of Blue Ridge triangulation, p. 28; plans for new primary base-apparatus, p. 51; report from the Computing Division, Coast and Geodetic Survey Office, pp. 57–60; terrestrial magnetism directions for magnetic observations with portable instruments by, Appendix No. 8, pp. 126–158; terrestrial magnetism, collection of results for declination, dip, and intensity, from observations made by the United States Coast and Geodetic Survey between 1833 and 1882, by, Appendix No. 9, pp. 159–224.
SCHROYER, AARON, OF FORT ROSS, CAL., p. 42.
SCHUYLKILL RIVER. Hydrography of, p. 3.
SCIENTIFIC PAPERS, METHODS, AND RESULTS CONTAINED IN THE APPENDICES TO THE ANNUAL REPORTS OF THE UNITED STATES COAST AND GEODETIC SURVEY, FROM 1845 TO 1880, INCLUSIVE. General index of, by C. H. Sinclair, Subassistant, Appendix No. 6, pp. 91–123.
SCORESBY (schooner). Use of, in Section II, p. 14; in Section III p. 24; relative to the, p. 65.
SEA CURRENTS, pp. 30, 31.
SEA-WALL. A rare formation found on end of Petit Manan Point, Me., p. 10.
SEBASTIAN CREEK, FLA., p. 31.
SEBREE, URIEL, LIEUTENANT, U. S. N. Hydrography of Mississippi River, p. 34; hydrography near Padre Island, coast of Texas, pp. 36, 37.
SEBREE GROUND. Developed by Lieutenant Sebree, p. 37.
SECTIONS OF WORK AS ARRANGED IN REPORT. Section I, pp. 10–14; Section II, pp. 14–22; Section III, pp. 22–28; Section V, pp. 28–29; Section VI, pp. 29–32; Section VII, p. 32; Section VIII, pp. 32–36; Section IX, pp. 36–37; Section X, pp. 37–42; Section XI, pp. 42–45; Section XII, pp. 45, 46; Section XIII, pp. 46, 47; Section XIV, pp. 47–49; Section XV, pp. 49–50; Section XVI, pp. 50, 51.
SEDALIA, MO., p. 50.
SENGTELLER, A. Engraving Division, Coast and Geodetic Survey Office, p. 64.
SENGTELLER, L. A., ASSISTANT. Triangulation and topography of California coast, pp. 41, 42; dangers to navigation reported north of Russian River, p. 42.
SHASTA. Station, p. 40.
SHERRELL, WIS. Station, p. 49.
SHIDY, L. P. Tidal Division, Coast and Geodetic Survey Office, p. 62.
SHIP JOHN, LIGHT, DELAWARE BAY. Hydrography of channel near, pp. 3, 18.
SHOALS, DEVELOPED OR REPORTED. Entrance to Salem Harbor, Mass., pp. 2, 3, 13; in Delaware Bay, p. 18; near port of Philadelphia, not found, p. 18; McCrie's, p. 18; at Maiden's Island, Delaware River, p. 19.
SHORT MOUNTAIN, TENN., p. 46.
SHUMAGIN ISLANDS, p. 45.
SIEMENS, OF LONDON. New electrical apparatus devised by, p. 30.
SIERRA NEVADA RANGE. Geodetic operations in, p. 4.
SIGSBEE, C. D., LIEUTENANT COMMANDER, U. S. N. Deep-sea soundings off Providence, R. I., with cylinder devised by, p. 29.
SILLIMAN (schooner). Laid up at Brooklyn, N. Y., p. 65.
SINCLAIR, C. H., SUBASSISTANT. Services in Section II, p. 17; triangulation of southern part of the District of Columbia, pp. 23, 24; telegraphic longitudes, p. 27; reference to triangulation of the District of Columbia in 1880, p. 59; general index of scientific papers, methods, and results contained in the appendices to the annual reports of the United States Coast and Geodetic Survey, from 1845 to 1880, inclusive, by, Appendix No. 6, pp. 91–123.
SIPE, E. H. Engraving Division, Coast and Geodetic Survey Office, p. 64.
SITE FOR NEW NAVAL OBSERVATORY. Topography of, p. 25.
SITKA, COAST OF ALASKA. Magnetic and current observations, soundings off, pp. 4, 45.
SKILLING RIVER. Progress of hydrography of, pp. 2, 10, 11.
SLAUGHTER STATION, MISSISSIPPI RIVER, p. 34.
SMITH, EDWIN, ASSISTANT. Azimuth observations at base lines in Kentucky and Louisiana, pp. 17, 24, 46; telegraphic longitudes, p. 27; reference to former triangulation of Mississippi River by, p. 35; present work on Mississippi River, p. 36; services in office of Coast and Geodetic Survey, p. 53.
SMITH, JAMES. Miscellaneous Division, Coast and Geodetic Survey office, p. 55.
SMITH'S GAP, PENN., p. 21.
SMOOT, J. H. Engraving Division, Coast and Geodetic Survey Office, p. 64.
SNOW HILL PUBLIC LANDING, MD., p. 22.
SOCORRO ISLAND, COAST OF CALIFORNIA, pp. 37, 38.
SOLAR ECLIPSE (total), of January 11, 1880, p. 40.
SOLDIERS' HOME, D. C., pp. 23, 24, 25.
SOMMER, E. J. Drawing Division, Coast and Geodetic Survey office, p. 63.
SOUTH CAROLINA. Survey of rivers on the coast of, reference to, in estimates, p. 5.
SOUTH MOUNTAIN, BLUE RIDGE, p. 27.
SPAULDING, J. G. Tidal observations at North Haven, Me., p. 11; services in Tidal Division, Coast and Geodetic Survey Office, p. 62.
SPECIAL HYDROGRAPHY OF OYSTER BEDS IN CHESAPEAKE BAY, pp. 22, 23.
SPECIAL OPERATIONS on Hudson River, p. 15; on Delaware River, p. 21.
SPECIAL TOPOGRAPHY of Columbia River, p. 43; see also Appendix No. 7, pp. 124, 125.
SQUARE BLUFFS, p. 51.
STAR STATION, N. Y., p. 16.
STATISTICS OF FIELD AND OFFICE WORK OF THE U. S. COAST AND GEODETIC SURVEY FOR THE YEAR ENDING DECEMBER 31, 1880. Appendix No. 2, pp. 73, 74.
STEADFAST (sloop). Use of, in Section VI, p. 31; relative to, p. 65.
STEEN'S LANDING, COAST OF CALIFORNIA, p. 41.
STEWART, G. A. In charge of archives of Coast and Geodetic Survey, p. 55.
STEWART, J. W., MASTER, U. S. N. Services in Section VIII, p. 34; in Section IX, p. 37.
STRAITS DE FUCA, WASH. TER., p. 4; reference to, in estimates, p. 7; hydrography of, p. 44.
STRASBURG, VA. Observatory erected at, pp. 3, 27.
STYLES MOUNTAIN, VT., p. 12.
SUESS, G. W. Temporarily in charge of observatory at Madison, Wis., pp. 49, 58.
SUESS, WERNER. Readjustment of instruments at observatory at Madison, Wis., pp. 49, 58; services in Computing Division, p. 57.
SUGAR LOAF, ILL., p. 48.
SULLIVAN FALLS, ME. Progress of hydrography of, pp. 2, 11.
SULLIVAN, J. A., ASSISTANT. Reference to former work in triangulation of Delaware River, pp. 18, 19.
SULLIVAN, ME., p. 10.
SUMMERSVILLE, W. VA., p. 28.
SUPERIOR CITY, WIS. Magnetic observations at, pp. 4, 47.
SUPPORTS. On the flexure of pendulum, by Assistant C. S. Peirce, Appendix No. 14, pp. 359–441.
SURVEY OF OYSTER BEDS IN CHESAPEAKE BAY, &c., pp. 2, 22, 23; see also Appendix No. 11, pp. 269–353.
SURVEYING PARTIES UPON THE ATLANTIC, GULF OF MEXICO, AND PACIFIC COASTS, AND INTERIOR OF THE UNITED STATES, DURING THE YEAR ENDING JUNE 30, 1881. Distribution of, Appendix No. 1, pp. 67–72.

SURVEYS IN AID OF THE U. S. GEOLOGICAL SURVEY, referred to in estimates, p. 7.

SWAN. Station in triangulation of D. C., p. 23.

SWATARA, LEBANON COUNTY, PENN., p. 21.

SWINBURNE, W. T., LIEUTENANT, U. S. N. Services in Section X, p. 38.

T.

TABLE MOUNTAIN, CAL., p. 39.

TABLE ROCK, W. VA., p. 28.

TAGGART'S POINT, DELAWARE RIVER, p. 19.

TAMPA BAY. Soundings off entrance to, p. 3; reference to, in estimates, p. 5; chart of coast from, to San Blas, referred to in estimates, p. 6.

TANEY, E. L., AID. Services in Section II, p. 17; in Section VI, p. 31.

TANGIER AND POCOMOKE SOUNDS, MD. AND VA., AND JAMES RIVER, VA. Report on the oyster beds of, by Lieut. Francis Winslow, U. S. N., Assistant, Coast and Geodetic Survey, Appendix No. 11, pp. 269–353.

TASSEL HILL, N. Y., p. 16.

TELEGRAPHIC LONGITUDES, p. 27.

TEMPERATURE OBSERVATIONS, p. 29.

TENALLYTOWN, D. C., pp. 23, 25.

TENNESSEE. Triangulation in, p. 46; referred to in estimates, p. 6.

TERRESTRIAL MAGNETISM. Directions for magnetic observations with portable instruments, by C. A. Schott, Assistant, Appendix No. 8, pp. 126–158; collection of results for declination, dip, and intensity, from observations made by the U. S. Coast and Geodetic Survey, between 1833 and 1882, by C. A. Schott, Assistant, Appendix No. 9, pp. 159–224.

TERRY, JR., CARLISLE, AID. Services in Section III, p. 27; in Section VIII, p. 36; in Section XIII, p. 46; in Section XV, p. 50.

TEXAS. Hydrography and topography of coast of, p. 3; referred to in estimates, p. 6.

THIRTY-NINTH PARALLEL, IN ILLINOIS, pp. 48, 50.

THOMAS, E. B., LIEUTENANT, U. S. N. Hydrography of Delaware Bay, p. 18; hydrography off Egmont Key and off Light House Point, Fla., p. 32; in charge of party on steamer A. D. Bache, p. 65.

THOMAS, M. Tidal Division, Coast and Geodetic Survey Office, p. 62.

THOMPSON, J. G. Engraving Division, Coast and Geodetic Survey Office, p. 64.

THOMPSON, W. Engraving Division, Coast and Geodetic Survey Office, p. 64.

TIBURON ISLAND. Magnetic observations on, p. 38.

TIDAL DIVISION, COAST AND GEODETIC SURVEY OFFICE. Report of, pp. 61, 62.

TIDAL OBSERVATIONS. Reference to, in estimates, pp. 5, 7; at North Haven, Me., p. 11; at Boston, Mass., p. 13; at Providence, R. I., p. 14; at Sandy Hook, p. 15; at Fort Sumter, S. C., pp. 28, 29; at Lake Borgne, La., p. 34; at Saucelito, Cal., p. 39; at Sandwich Islands, p. 42; at Kadiak, Alaska, p. 45.

TIDE GAUGE. At Providence R. I., p. 14; at Club House wharf, Jamaica Bay, p. 14; at Sandy Hook, p. 15; in Chincoteague Bay, p. 22; sent to Charleston at request of Gen. Q. A. Gillmore, pp. 28, 29; one constructed under supervision of Chief of Tidal Division for Gen. B. M. Harrod, of La., p. 34; at Saucelito, Cal., p. 39; at Sandwich Islands, p. 42; at Kadiak, p. 45; relative to, p. 61.

TIDES IN DELAWARE BAY. New rule for, by Henry Mitchell, Assistant, Appendix No. 18, pp. 464–469.

TIDE TABLES for 1882, completed and published, p. 62.

TIPTON, p. 50.

TIP TOP HOUSE, MT. WASHINGTON, p. 12.

TITTMANN, O. H., ASSISTANT. Relative to permanent trial base at Fort Myer, D. C., p. 26; primary triangulation eastward from the El Paso base, p. 51; special duty in Coast and Geodetic Survey Office, p. 53; on a method of readily transferring the underground mark at a base monument, by, Appendix No. 13, pp. 357, 358.

TODOS SANTOS. Magnetic observations at, p. 38.

TOPOGRAPHY, COLUMBIA RIVER. Type forms of, by E. Hergesheimer, Assistant, Appendix No. 7, pp. 124, 125.

TOPOGRAPHY. Progress of, pp. 2–4; reference to, in estimates, pp. 5–8; of Dyer's Neck and Petit Manan Point, Me., p. 10; of Frenchman's Bay, Me., p., 10; of south coast of Long Island, p. 14; of Hudson River, p. 15; near Cape May, N. J., p. 17; of the Delaware River, p. 19; of, and triangulation of Delaware River, pp. 19, 20; of the District of Columbia, pp. 24, 25; of site for new Naval Observatory in D. C., p. 25; and triangulation of Indian River, Fla., p. 30; of the Laguna Madre, Tex., p. 36; near San Luis Obispo, Cal., pp. 38, 39; of coast of California, p. 41; of Columbia River, p. 42; special, of Columbia River, p. 43; see also Appendix No. 7; of Port Orchard and Puget Sound, p. 43.

TOTAL SOLAR ECLIPSE OF JANUARY 11, 1880. Report of observations on, by Assistant George Davidson, p. 40.

TOWN HALL, WILMINGTON, DEL., p. 20.

TREATISE ON THE PLANE TABLE. New edition, prepared by Assistant Hergesheimer, p. 43.

TRIANGULATION. Progress of, pp. 2–4; referred to in estimates, pp. 5–7; of New Hampshire, p. 12; of Vermont, p. 12; near Cape May, N. J., p. 17; of the Delaware River, pp. 18, 19; and topography of Delaware River, pp. 19, 20; in New Jersey, p. 21; in Pennsylvania, p. 21; of the District of Columbia, p. 23; of the D. C. (southern portion), p. 24; in W. Virginia, pp. 27, 28; and topography of Indian River, Fla., p. 30; of the Mississippi River, pp. 34–36; in Louisiana, p. 35; of coast of California, p. 41; of Columbia River, p. 42; of Port Orchard and Puget Sound, p. 43; in Tennessee, p. 46; in Ohio, p. 47; in Indiana, pp. 47, 48; and reconnaissance in Illinois, pp. 48, 49; in Wisconsin, p. 49; primary, in Missouri, p. 49; (primary) eastward along 39th parallel in Nevada, p. 50; (primary) eastward from the El Paso base, p. 51.

TROY, N. Y., p. 13.

TURKEY CREEK, FLA., p. 31.

TURKEY HILL, ILL., p. 48.

TURNBULL, C. B. Computing Division, Coast and Geodetic Survey Office, p. 60; in Tidal Division, p. 62.

TURTLE GUT INLET, N. J., p. 17.

TWO MILE BEACH, N. J., p. 18.

TYPE FORMS OF TOPOGRAPHY, COLUMBIA RIVER, BY E. HERGESHEIMER, ASSISTANT. Appendix No. 7, pp. 124, 125.

U.

UNALASHKA, p. 45.

UNALASHKA HARBOR, p. 46.

UNITED STATES. Magnetic survey of the, necessity for and progress of, p. 1.

UNITED STATES COMMISSION ON FISH AND FISHERIES. Dredging in Gulf Stream in connection with, referred to in estimates, p. 5.

UNITED STATES COMMISSIONER ON FISH AND FISHERIES. Reference to, p. 45.

UNITED STATES ENGINEER CORPS, U. S. A. Work for the, done in Electrotyping and Photographing Division, p. 54; tide gauge loaned to, p. 61.

UNITED STATES GEOLOGICAL SURVEY. Surveys in aid of reference to, in estimates, p. 7.

UNITED STATES NAVAL OBSERVATORY AT WASHINGTON (new). Topographical survey for site of, pp. 3, 25.

UNITED STATES NAVAL OBSERVATORY (old). Point in the triangulation of the District of Columbia, pp. 3, 23, 24, 59; longitude instruments placed in position at, p. 17.

UNIVERSITY GROUNDS, NASHVILLE, TENN. Astronomical station erected in, p. 46.

UTAH. Magnetic observations in, pp. 4, 50; triangulation across, referred to, in estimates, p. 7.

V.

VACA STATION, p. 39.

VALUE OF GRAVITY AT PARIS, ON THE, BY C. S. PEIRCE, ASSISTANT. Appendix No. 17, pp. 461–463.

VAN ORDEN, C. H., AID. Services in Section II, p. 15; in Section VII, p. 34.

VENADO STATION, TEX., p. 36.

VERMONT. Triangulation of, pp. 2, 12; primary triangulation in, pp. 12, 13; reference to, in estimates, p. 5.

VERSAILLES, MORGAN COUNTY, MO., p. 49.

VERY, LIEUTENANT, U. S. N. Use of magnetic observatory at Washington by, for testing instruments for expedition to northeast coast of America, p. 25.

VICKSBURG, MISS. Triangulation of the Mississippi River near, pp. 3, 32, 35.

VIERBUCHEN, P., MISCELLANEOUS DIVISION, COAST AND GEODETIC SURVEY OFFICE, p. 55.

VINAL, W. I., SUBASSISTANT. Services in Section I, p. 10; in charge of Engraving Division, Coast and Geodetic Survey Office, p. 10; triangulation, topography, and hydrography of Indian River, Fla., p. 30; services in Section VI, p. 31.

VINCENNES, IND. Magnetic observations at, pp. 4, 47.

VIRGINIA. Triangulation near boundary of Maryland and, p. 27; reference to, in estimates, p. 5.

W.

WABASH RIVER, p. 48.

WAINWRIGHT, D. B., SUBASSISTANT. Services in Section X, p. 39.

WALALLA RIVER, CAL., pp. 4, 41.

WALDWICH STATION, WIS., p. 49.

WALLA WALLA, COLUMBIA RIVER, p. 43.

WALLING, H. F. Observations in Maryland for compilation of general hypsometric map, pp. 26, 27.

WALNUT COVE. Tide gauge at, used in work in Salem Harbor, Mass., p. 13.

WALNUT POINT. Triangulation of Mississippi River near, pp. 3, 35.

WANDALL, C. F., LIEUTENANT, ROYAL DANISH NAVY. Accompanying party on steamer Blake, p. 30.

WAR DEPARTMENT. Reference to expedition to Arctic regions sent out by, p. 1.

WASHINGTON CITY, D. C. Telegraphic longitude signals at, pp. 3, 17, 27; magnetic observatory at, p. 25; pendulum observations at, p. 26; Coast Survey vessels laid up at, p. 65.

WASHINGTON HARBOR, WASH. TER., p. 44.

WASHINGTON MONUMENT. Point in triangulation of the District of Columbia, p. 24.

WASHINGTON TERRITORY. Preparation of new edition of Coast Pilot for, p. 2; reference to, in estimates, p. 7; off-shore soundings coast of, reference to, in estimates, p. 7.

WASSERBACH, T. Engraving Division, Coast and Geodetic Survey Office, p. 64.

WEIR, J. B., SUBASSISTANT. Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.

WELKER, P. A., AID. Services in Section XI, p. 44.

WEST BASE MONUMENT, p. 51.

WESTERN DIVISION OF THE COAST AND GEODETIC SURVEY. Reference to, in estimates, p. 7; special magnetic operations in, under head Section X, p. 10.

WESTERN UNION TELEGRAPH COMPANY. Facilities afforded by, p. 47.

WEST INDIES. Reference to route taken by Columbus in his first voyage to America, p. 58.

WEST POINT, N. Y. Topography of Hudson River near, pp. 2, 15, 16; reference to, in estimates, p. 5.

WEST VIRGINIA. Positions for triangulation in, pp. 3, 27, 28; reference to, in estimates, p. 5.

WHEELING, W. VA. Magnetic observations at, pp. 3, 27.

WHITEHALL, N. Y., p. 13.

WHITING, H. L., ASSISTANT. Topography of Hudson River, p. 15.

WIGGIN, F. E. Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.

WILLAMETTE SLOUGH, COLUMBIA RIVER, p. 43.

WILLARD STATION, D. C., p. 24.

WILLENBUCHER, E. Hydrographic Division, Coast and Geodetic Survey Office, pp. 54, 66.

WILLENBUCHER, W. C., HYDROGRAPHIC DRAUGHTSMAN. Services in Section III, pp. 22, 23; Hydrographic Division, Coast and Geodetic Survey Office, p. 66.

WILLIAMS STATION, KY., p. 46.

WILLIAMSON, LIEUT. COL. A. S., U. S. ENGINEER CORPS. Reference to, p. 42.

WILLOW GROVE STATION. Remarking of, on Delaware River, p. 21.

WILMINGTON, DEL. Triangulation of Delaware River near, p. 20.

WILNER, FRANK A., MASTER, U. S. N. Services in Section VI, p. 31; in section VII, p. 32.

WINES, M. W. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

WINSLOW, FRANCIS, MASTER, U. S. N. Survey of oyster beds in Chesapeake Bay in 1878, '79, p. 2; reference to, p. 22; see also Appendix No. 11, pp. 269–353.

WINSTON, ISAAC, AID. Services in Section XIV, p. 48; in Computing Division, Coast and Geodetic Survey Office, pp. 57, 60.

WINTERPORT, PENOBSCOT RIVER, pp. 2, 11.

WINYAH BAY. Chart of coast from, to Long Island, p. 6.

WISCONSIN. Triangulation in, pp. 4, 49; referred to in estimates, p. 6; magnetic observations in, p. 47.

WOOD, M. L., ENSIGN, U. S. N. Services in Section VIII, p. 34; in Section IX, p. 37.

WOODBURY CREEK, N. J., p. 3.

WOODLAND, CAL. Leveling operations near, p. 40.

WOODY ISLAND, CHESAPEAKE BAY, p. 23.

WORMELSDORF STATION, PENN., p. 21.

WYTHEVILLE, VA. Magnetic observations at, pp. 3, 27.

WYVILL, E. H., RECORDER. Services in Section II, p. 18.

Y.

YANKTON, DAK. Magnetic observations at, pp. 4, 50.

YARD. Station on Delaware River, recovered and secured, p. 21.

YARNALL'S. Triangulation station on Delaware River, p. 19.

YEATMAN, A. Miscellaneous Division, Coast and Geodetic Survey Office, p. 55.

YOLO BASE LINE, pp. 4, 39, 40.

YOLO COUNTY, CAL., p. 4.

YORK, ENGLAND. Meeting of British Association for Advancement of Science held at, p. 2.

YUKON (schooner). Use of, in Section XII, pp. 45, 46; relative to condition of the, p. 65.

Z.

ZUMBROCK, A. In charge of Electrotyping and Photographing Division, Coast and Geodetic Survey Office, p. 54.

# REPORT.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
*Washington, D. C., December* 23, 1881.

SIR: I have the honor to transmit herewith a report of the operations of the Coast and Geodetic Survey of the United States for the fiscal year ending June 30, 1881. Owing to the death of Mr. Carlile P. Patterson, LL. D., my predecessor in office, before his annual report was made, the duty of preparing this account of the operations of the survey carried on under his direction has devolved upon me.

The work along the unsurveyed portions of the Atlantic, Pacific, and Gulf coasts has been well advanced, and, as means would permit, the exploration of the coast of Alaska has been continued for the correction of the charts and sailing directions of that Territory. Valuable magnetic, current, tidal, and sea-water temperature observations have also been obtained along that coast.

In the interior States and Territories the triangulation along the thirty-ninth parallel of latitude to connect the Atlantic and Pacific coast systems of triangulation has been carried forward from several points simultaneously, and the geodetic schemes of both coasts have been extended inward, with the object of an ultimate junction of the whole work into one connected system. Incidental to these operations, a line of geodetic levels has been extended from the eastern coast towards the Pacific, from which, eventually, subsidiary lines will be carried to the primary triangulation points with a view to a final reduction to the sea level.

The validity of all geodetic work depending in a great measure upon our knowledge of the exact figure of the earth, measurements of the force of gravity by means of the pendulum have been continued as heretofore at suitable stations on the Atlantic coast. For the execution of this important and difficult work improvements have recently been devised in methods and instruments employed, promising in the future results of a greater accuracy and precision than was hitherto attainable.

In connection with the party sent to Point Barrow, in the Arctic regions, under charge of Lieut. Henry P. Ray, U. S. A., by the War Department, for the purpose of establishing a meteorological observatory at that extreme northern point of the American continent, an observer trained at this office for pendulum observations, and supplied with the needful instruments, was engaged to accompany the expedition and make a series of observations at that locality. Similar observations will also be made by the expedition to Lady Franklin Bay, and the magnetic elements will be observed at both localities.

Telegraphic longitudes of several points in the interior have been determined during the year. The methods and apparatus used in telegraphic longitude work have also been considerably improved, reducing the probable error of a determination to a minimum. Progress in this branch has been greatly facilitated by the co-operation of the telegraphic companies, which have afforded every assistance in regard to the exchange of signals over their lines.

The magnetic survey of the United States has been advanced by numerous observations at interior and outlying stations, and the data thus obtained will form a valuable addition to our knowledge of the present condition of the magnetic declination in the United States and of the laws which govern its change. The great demand for these results from all parts of the Union is sufficient evidence of the practical importance of the work.

The development of the Gulf Stream, Gulf of Mexico, and Caribbean Sea by deep-sea soundings, serial temperatures, current observations, and dredgings, has been efficiently continued by Commander J. R. Bartlett, with the party on board the steamer Blake. The results of this work will be noticed in detail under its proper head. A new electrical apparatus for recording serial temperatures has been put in operation on board the Blake, and promises to be a most valuable adjunct in the execution of this class of work.

Tidal observations have been recorded as usual at the principal ports of the United States, and at outlying points several new stations have been established. Work on the Coast Pilot for the Atlantic coast has been continued by Assistant J. S. Bradford, who has been engaged during a portion of the year in collecting notes and data to be embodied in future volumes. Division C, New York to Chesapeake Bay, is now in course of publication.

On the Pacific coast, Assistant George Davidson has been engaged in the preparation of a new edition of the Coast Pilot of California, Oregon, and Washington Territory.

An appendix to the Alaska Coast Pilot, by Assistant W. H. Dall, relating to the meteorology and bibliography of Alaska, has been completed and published. The field-work of Assistant Dall, on the coast of Alaska, will be fully noticed in the body of this report.

Prof. William Ferrel has continued his meteorological researches for the Coast Pilot, and has completed a second volume on that subject. He has also prepared a paper on barometric hypsometry and a chapter on the practical application of the formula developed.

The survey of the oyster-beds in the Chesapeake Bay was commenced by this Survey in 1878, the general object being primarily to determine the positions, limits, formation, and general features of the principal oyster localities, and, incidentally, to gather all available information in regard to the growth of the oyster and the conditions favorable for its propagation, as well as those having a contrary tendency. This work was begun under the direction of Lieut. Frederick Collins, U. S. N., and was afterwards taken up by Master Francis Winslow, U. S. N., in the Coast and Geodetic Survey schooner Palinurus. The results of his labors have been embodied in one of the Annual Reports of the Fish Commissioners of the State of Maryland. (See also Appendix 12.) On the detachment of Master Winslow from the Survey in January, 1880, the work was taken up by Assistant Gershom Bradford, who has continued it with valuable results to the close of the year.

In order that the Coast and Geodetic Survey might be represented at the meeting of the British Association for the Advancement of Science to be held at York, England, in the month of August, and for the purpose of investigating several important scientific problems cognate to the work, Dr. Thomas Craig was directed in April last to proceed to Europe, under authority obtained from the Treasury Department and with special instructions from this office. Dr. Craig sailed for Europe early in May, and at the close of the fiscal year was engaged in carrying out the objects of his trip.

The condensed abstract here given contains a statement of the various localities at which work was prosecuted during the year, following the same geographical arrangement adopted for the detailed notices in the body of this report.

The work done on the Atlantic coast during the year ending June 30, 1881, has included the following operations: Topography between Dyer's Neck and Petit Manan Point, Me.; plane-table survey of the shores and upper heads of Frenchman's Bay, Me.; hydrography of the Penobscot River, Me., between Hampden and Winterport; hydrography of the headwaters of Bagaduce River, of Jordan River, of Skilling River, of a portion of Frenchman's Bay, and of Franklin Bay above and including Sullivan Falls, Me.; examination for location of a buoy in Mill Creek Reach, Penobscot River, Me.; continuation of tidal observations and of meteorological observations at North Haven, entrance of Penobscot Bay, Me.; hydrographic resurvey of Rockland Harbor, Me., and soundings in Muscle Ridge Channel, Me.; observations commenced at the triangulation station on Mount Washington, N. H., and signals re-erected to be observed on from Gill Hill, Vt.; observations completed at triangulation stations Herrick and Northeast Mountain, in Vermont; primary triangulation continued in Vermont to connect the survey of Lake Champlain with the triangulation of the coast; observations completed at Potato Hill and Fields Hill, Vt., and at Cheever and Blueberry Hill, in New York; hydrographic development of Pickett's Ledge, entrance to Salem Harbor, Mass.; topography and hydrography continued along the south coast of Long Island, including a survey of Cornell's Creek; observations continued with self-registering tide gauge at Sandy Hook, N. J.; remarking trigonometrical points on the Hudson River; topography of the shores of the Hudson River in the vicinity of West Point, N. Y., and points established by triangulation for the plane-table survey; reconnaissance continued across the northern part of the State of New York for triangulation between Lake Champlain and Lake Ontario; observations completed at Bigelow Station, N. Y., in scheme of primary triangulation to connect Lake Champlain with the coast triangulation; astronomical observatory erected and telegraphic longitudes determined by signals between Cape May, N. J., and Washington, D. C.; triangulation points determined and topography of the coast continued in the vicinity of Cape May, N. J.; hydrography of main ship channel, Delaware Bay, from Ship John Light towards Brandywine Shoal Light; of Delaware Bay near the mouth of Cohansey Creek; special surveys for the Light-House Board of a shoal near the Fourteen Foot Bank; for position of a light-house near Lewes, Del.; detailed survey of that bank and of the lower end of Joe Flogger Shoal; survey of Cape May to and including Brown Shoal; triangulation of the Delaware River from New Castle to Delaware City; topography of the Delaware River from Fort Mifflin to Chester, Pa., and of the shores of New Jersey from Woodbury Creek to Raccoon Island; triangulation of the Delaware River from Chester, Pa., to New Castle, Del., and triangulation and topography from Raccoon Island to Penn's Grove, N. J.; hydrography of the Delaware River from the upper end of Little Tinnicum Island to the upper end of Marcus Hook, and from Edgemoor to above New Castle, Del.; and from near the mouth of the Schuylkill River towards Chester, Pa.; triangulation continued in the northern part of New Jersey; five stations occupied and two new stations established in the triangulation of Pennsylvania; examination of inland waters between Montauk Point, Long Island, and Cape Charles, Va., for the preparation of a coast directory for small craft, and coast views obtained off Cape Henry, Va.; hydrography of inland waters along the coast of Maryland and Delaware north of Chincoteague Inlet; examination of oyster-beds in Chesapeake Bay, and survey of shoals off Chincoteague Inlet; triangulation points determined for a plane-table survey of the District of Columbia; triangulation of District of Columbia completed, and pier at Fort Myer connected by triangulation with the United States Naval Observatory for use in experiments relative to the velocity of light; topography continued for a detailed survey of the District of Columbia; topographical survey of a site for the new Naval Observatory; pendulum observations and collateral work continued at the Johns Hopkins University, Baltimore, Md.; barometric and other observations commenced at points in Maryland for the compilation of a general hypsometric map; astronomical observatories erected at Strasburg, Va., and Charleston, W. Va., and telegraphic longitude signals exchanged between those stations and Washington, D. C., with observations for latitude at the first two stations; magnetic declination, dip, and intensity determined at Wheeling, Clarksburg, Parkersburg, Charleston, and Alderson, W. Va., Covington and Wytheville, Va., and observations partially completed at Marion, Va.; stations in West Virginia occupied for extending westward the triangulation towards the Ohio River; tidal observations at Charleston, S. C., deep-sea soundings, dredgings, and temperatures between George's Bank and Charleston, S. C.; soundings between Jupiter Inlet, Fla., and Currituck Light House, N. C., extending across to the Bahama Banks, with serial temperatures and dredgings for bottom specimens; triangulation, topography, and hydrography of Indian River and adjacent coast, eastern Florida; lines of soundings run off Cape Canaveral Shoals and south of Cape Canaveral, east coast of Florida; lines of soundings run off Egmont Key, entrance to Tampa Bay; and off Light House Point, east end of Saint George's Sound, west coast of Florida; hydrography of the Mississippi River from a point four miles below Donaldsonville, La., to Plaquemine; tidal observations at Lake Borgne, La.; triangulation of the Mississippi River completed between Bayou Sara and Baton Rouge, La.; triangulation of the Mississippi River from Providence, La., connected at Walnut Point with scheme extended from Greenville, Miss.; lines of precise levels run from Point Coupée, La., to Rodney, Miss.; triangulation of the Mississippi River completed between Vicksburg, Miss., and Lake Providence, La., and between Greenville, Miss., and Walnut Point, Miss.; lines of precise levels run from Greenville, Miss., to Glenora, Miss., along the Mississippi River, and from Glenora, Miss., to Rodney, Miss.; base line measured at Greenville, Miss., and triangulation commenced; azimuth determined at the base line near Greenville, Miss.; topography continued of the Laguna Madre near Corpus Christi, Texas; hydrography of the coast of Texas off Padre Island.

On the Pacific coast of the United States the operations of the Survey, commencing at the south and going northward, have included the determination of magnetic declination, dip, and intensity at stations on the coasts of Central America, Mexico, and Lower California, and a reconnaissance of Guadalupe Island; observations with a self-registering tide-gauge and meteorological observations at Mazatlan, Mexico; hydrography of the coast completed between Point Arguello and Point Sal, Cal.; topography of the coast in the vicinity of San Luis Obispo, Cal.; observations continued with the self-registering tide-gauge at Saucelito, inside of San Francisco Bay, Cal.; Sanhedrin and Cahto stations occupied in scheme of primary triangulation north of San Francisco Bay, Cal.; geodetic operations, including latitude, azimuth, and magnetic observations at stations in the Sierra Nevada range, for the trans-continental triangulation, and site prepared for a primary base-line in Yolo County, Cal.; triangulation and topography of the California coast from Walalla River to Point Arena, Cal.; observations of tides continued at the self-registering tide-gauge at Honolulu, Sandwich Islands; detailed topographical survey of the Columbia River continued from Columbia City to above Saint Helen's; special topography of the valley of the Columbia River, including the Dalles; Coast Pilot views for the Columbia River, Oreg.; hydrography commenced and triangulation extended in that vicinity; topography of Port Orchard, Wash. Ter., and adjacent shores and inlets of Puget Sound, and triangulation extended to furnish necessary points; hydrography of Port Discovery and adjacent waters, Straits of Juan de Fuca, Wash. Ter.; reconnaissance for a primary base-line site on the shore of Boundary Bay, British Columbia; tidal observations continued with the self-registering tide-gauge at Saint Paul's, Kadiak Island, Alaska; astronomical, magnetic, meteorological, current, and sea-water temperature observations, with soundings, at stations between Sitka and Chilkaht, coast of Alaska, collection of notes for the Coast Pilot of Alaska.

In the interior, work for the year has included determination of azimuth at the base-line near Louisville, Ky.; reconnaissance for scheme of primary triangulation to connect the Louisville base and Salt River with the line Riley to Mountain Top, in Northern Kentucky; observations completed at four stations, signals erected, and one station reoccupied in scheme of primary triangulation in Tennessee; reconnaissance for the extension of the primary triangulation in Ohio; astronomical observatory erected for telegraphic longitude observations at Cincinnati, Ohio; magnetic declination, dip, and intensity determined at Cleveland, Ohio; Grand Haven, Mich.; Macinac, Mich.; Sault Ste. Marie, Mich.; Ontonagon, Mich.; Superior City, Wis.; Vincennes, Ind.; New Harmony, Ind.; Indianapolis, Ind.; Richmond, Ind.; Cincinnati, Ohio; and Athens, Ohio; reconnaissance for the scheme of primary triangulation in Indiana, continuation of, and reconnaissance for the primary triangulation eastward along the thirty-ninth parallel in Illinois; four stations occupied and observations made for latitude and azimuth at two stations in the triangulation of Wisconsin; observations of magnetics continued at the magnetic observatory, Madison, Wis.; primary triangulation extended westward in Missouri from stations Hunter and North Base; magnetic elements determined at Brainerd, Minn.; Glyndon, Minn.; Pembina, Dak.; Jamestown, Dak.; Bismarck, Dak.; Fort Snelling, Minn.; Heron Lake, Minn.; Yankton, Dak.; Omaha, Nebr.; and Dubuque, Iowa; primary triangulation in Nevada continued eastward along the thirty-ninth parallel, and magnetic elements determined at stations in Nevada and Utah Territory; and primary triangulation in Colorado extended eastward from the El Paso base.

## ESTIMATES.

The estimates submitted to Congress for the service of the next fiscal year are intended to provide for the continuance of surveying operations upon a basis commensurate with the necessities of the work, and to restore the appropriations to an amount from which they were reduced some years since in a time of great commercial depression. In order that the work may be done most economically, a just proportion must be maintained between the amount available for field-work and that necessarily absorbed in preserving an efficient organization to meet the requirements of the case. An organization which depends for its efficiency on the professional acquirements and years of special training of its members cannot be annually increased or decreased at will in its essential features. It must conform to a certain standard, and be sufficiently large to achieve and make available as quickly as possible results commensurate with the constantly increasing demand for them arising from, and corresponding to, the rapid growth of the country. These considerations, and the fact that experience has proven the relative economy of the larger appropriations, make it a duty to point out that a recurrence to the latter is urgently needed.

The estimates for continuing work in the Eastern Division of the Coast and Geodetic Survey during the year ending June 30, 1883, are intended to provide for the following progress:

FIELD-WORK.—To continue the topography of the coast of Maine east of Frenchman's Bay; to determine heights at geodetic points between Boston and the Saint Croix; and coefficient of refraction; to complete the hydrography between Frenchman's Bay and Moose-a bec Reach, and continue soundings in the coast approaches eastward of Petit Manan Island; to continue a topographical and hydrographic survey of Portsmouth Harbor, and make such additional triangulation as may be required for that and other surveys on the eastern coast; to continue the triangulation of New Hampshire; to determine the position of new light houses between Eastport, Me., and New York; to continue the triangulation of Vermont; to continue soundings off the coast of Maine, and other off-shore hydrography between Capes Manan and Cod, and make special examination for the sailing lines for charts; to continue the observations of sea and tidal currents in the Gulf of Maine; to continue tidal observations, and to make such astronomical and magnetic observations as may be required; to continue the survey of the Connecticut River from its mouth to Hartford; to make such examinations as may be required in New York Harbor, and such surveys in its vicinity as may be necessary, including the continuation of the topographical and hydrographic survey of the south coast of Long Island; to make along this part of the coast observations of tides and currents; to continue the plane-table survey of the shores of the Hudson River above West Point; to continue triangulation between Hudson River and the north end of Lake Champlain, and between Lake Champlain and Lake Ontario; to make the requisite astronomical observations; to continue the topographical and hydrographic survey of the coast of New Jersey; to continue the triangulation of New Jersey and Pennsylvania; to connect the Atlantic coast triangulation with that of the Chesapeake Bay near the boundary line between Maryland and Virginia; to continue the plane-table survey of the Potomac River; to continue westward the main triangulation from the Atlanta base to the Mississippi River at or near Memphis, including astronomical and magnetic observations; to continue the supplementary hydrography between Cape Henlopen and Cape Henry, and the tidal observations, including also such as may be required in Chesapeake Bay; to continue westward the triangulation in West Virginia along the thirty-ninth parallel; to measure base lines of verification and determine azimuths for the coast triangulation south of Cape Lookout; to make astronomical and magnetic observations requisite; to continue the off-shore hydrography between Cape Henry and Cape Fear; to sound the entrance to Cape Fear River; to continue the topographical and hydrographic survey of rivers on the coast of South Carolina and Georgia; to continue the off-shore hydrography between Cape Fear and the Saint John's River, Fla.; to continue southward from Indian River the triangulation, topography, and hydrography of the eastern coast of Florida to Key Biscayne Bay; to continue the triangulation, topography, and hydrography of Saint John's River; to make the requisite astronomical observations; to continue hydrography off the eastern coast of Florida from Indian River to the southward; to continue soundings and observations for deep-sea temperatures, currents, and dredgings in such parts of the Gulf Stream, northward of the latitude and eastward of the meridian of Cape Florida, as may be deemed advisable, and also in the Caribbean Sea; and, within the same limits, such as may be considered advantageous in conjunction with the United States Commission on Fish and Fisheries; to continue the astronomical and magnetic observations requisite throughout the Gulf of Mexico; to continue the triangulation, topography, and hydrography of the western coast of Florida between Cedar Keys and Tampa Bay, and between Tampa Bay and Charlotte Harbor; to continue the same classes of work to the southward of Charlotte Harbor; to connect the trigonometrical survey of the Mississippi River at New Orleans with that of Lake Borgne, Lake Pontchartrain, and Maurepas; to continue the triangulation, topography, and hydrography of the Mississippi River above New Orleans to the head of ship navigation; to determine geographical positions, and make the astronomical and magnetic observations requisite; to extend the triangulation, topography, and hydrography of the coast of Louisiana westward of the Mississippi delta, and continue the hydrography of the Gulf of Mexico between the mouths of the Mississippi and Galveston, Texas; to continue the triangulation, topography, and hydrography of the coast of Texas westward between Sabine Pass and Galveston, and between Corpus Christi and the Rio Grande; to measure a base line of verification and make the astronomical and magnetic observations requisite between Sabine Pass and the Rio Grande;

to continue the hydrography of the approaches to the coast of Texas; to continue the triangulation across the States of Ohio, Indiana, Illinois, Missouri, and Kansas, for the connection of the surveys of the Atlantic and Pacific; and continue triangulation in Kentucky, Tennessee, and Wisconsin; to furnish points for State surveys; to continue the determination of positions of new light-houses and life-saving stations along the coast between New York and the Rio Grande; to continue field-work for the verification of data for the Coast Pilot; to continue the organized system of magnetic observations required for a complete magnetic survey, and to run lines of levels connecting points in the main triangulation with the sea level.

OFFICE-WORK.—To continue the deduction of results by computation from the field operations along the Atlantic and Gulf coasts, and in connection with the geodetic surveys of the interior, including astronomical, geographical, magnetic, hypsometric, and tidal work; to advance the publication of the Coast Pilot for the Atlantic and Gulf coasts, and to complete tide predictions for the year 1883 for those coasts; to continue the preparation of topographical and hydrographic maps and charts, and the maps and charts derived therefrom, for publication, and to plot the hydrographic surveys; to continue the drawings of sailing charts No. 1, from Cape Sable to Sandy Hook, and "A" from Cape Sable to Cape Hatteras, with sub-charts; also the drawings of general coast chart, Quoddy Head to Cape Cod (eastern part), and of coast chart No. 3, Frenchman's, and Blue Hill Bays; to complete the drawing of the general chart of the Atlantic coast from Quoddy Head to Cape Cod (western part), and to begin the drawings of coast chart No. 2, Machias Bay to Prospect Harbor, and of the chart of Pleasant Bay; to finish the engraving of the chart of the approaches to Blue Hill Bay and Eggemoggin Reach; to continue the drawing of sailing chart No. 2 of the Atlantic coast from Nantucket to Cape Hatteras, and to begin the drawing of the new edition of coast charts Nos. 19 and 26, Hempstead and Great South Bays, Long Island; and Delaware River, Port Penn to Trenton; to complete the drawing of coast chart No. 23, Cape May to Absecon Inlet, also the drawing and engraving of the chart of James River from City Point to Kingsland Creek, and to begin the drawing and engraving of the chart of the same river from Kingsland Creek to Richmond; to continue the drawing of the sailing chart of the Atlantic coast from Cape Hatteras to Key West (with sub-charts), and to complete that of the general chart of the coast from Cape Hatteras to Cape Romain; to begin the drawing of the chart of Cape Fear River (new edition), and to continue the engraving of coast charts Nos. 46, 47, 48, and 49, including the Atlantic coast from Ocracoke Inlet to Cape Fear; to continue the drawing of sailing chart of the coast from Cape Hatteras to Mosquito Inlet; to continue the engraving of coast chart No. 51, part of Long Bay, including Little River Inlet, and to complete that of coast chart No. 53, from Winyah Bay to Long Island; to complete the drawing of the general chart of the coast from Cumberland Sound to Cape Cañaveral; to continue the drawing and to begin the engraving of the general coast chart from Cape Cañaveral to Cape Florida; to finish the engraving of the charts of the Saint John's River from Jacksonville to Green Cove Springs, and from Green Cove Springs to Federal Point; also the engraving of coast chart No. 61, from Mosquito Lagoon to Cape Canaveral; to begin the drawing of the coast chart of Indian River and Indian River Inlet, and to continue that of the sailing chart from Mosquito Inlet to Key West with the Bahama Banks; to begin the drawing and engraving of the general chart of the coast from Key West to Tampa Bay; to complete the drawing and to begin the engraving of the general coast chart, Tampa Bay to Cape San Blas; to continue the drawings of sailing charts, Key West to the Rio Grande, Gulf of Mexico in four sheets, and the drawing and engraving of the chart of the Gulf of Mexico in one sheet; to continue the engraving of coast chart No. 80, from Cedar Keys northward, and to complete that of coast chart No. 84, from Saint Joseph's Bay to Saint Andrew's Bay; to continue the engraving of coast chart No. 87, from Pensacola Entrance to Mobile Bay, and to complete that of coast chart No. 92, Chandeleur, and Breton Island Sounds; to continue the drawing and engraving of the general chart of the coast from Galveston to the Rio Grande; to begin the engraving of coast charts Nos. 110, 111, and 112, from Corpus Christi Bay to the Rio Grande; for material for drawing, engraving, chart printing, for electrotyping and photographing, and for instruments and apparatus.

Total for the Eastern Division, including the Atlantic and Gulf coasts, and involving work in thirty-two States and three Territories, will require $373,000.

For the completion of the resurvey of Delaware Bay and River, $10,000.

The estimates for continuing work in the Western Division of the Coast and Geodetic Survey during the year ending June 30, 1883, are intended to provide for the following progress:

FIELD-WORK.—To make the requisite observations for latitude, longitude, azimuth, and the magnetic elements at stations along the Pacific coast of the United States; to continue off shore soundings along the coast of California, Oregon, and Washington Territory, and tidal observations at San Francisco and such other localities as may be necessary; to continue the main coast triangulation from Monterey Bay to the southward, and from Point Concepcion to the northward, and from San Pedro towards San Diego; to continue the main triangulation of the coast from Cape Mendocino to the northward; from Columbia River north to Puget Sound; to measure base-lines of precision in the Western Division of the Survey; to continue the coast triangulation and topography from Newport, Los Angeles County, Cal., towards San Diego; to continue the hydrography between San Diego and Monterey Bay; to develop hydrographic changes in San Francisco Bay and its approaches; to continue triangulation across the States of California, Nevada, Colorado, and Territory of Utah, along the thirty-ninth parallel, for connecting the survey of the Pacific coast with that of the Atlantic, and furnish points for the survey of the States named; to complete the secondary and tertiary triangulation, and the topography of the coast between Bodega Bay and Point Arena; to continue soundings between Cape Mendocino and the Klamath River, and between Cape Sebastian and Point Orford; to observe currents along the coast and take soundings and temperature observations in the California branch of the Kuro Siwo current, and execute such other hydrographic work as local demands may require; to continue tidal and current observations at the Golden Gate, and observations of ocean currents along the coast of California; to continue the triangulation, topography, and hydrography of the Columbia River; to complete the detailed survey between Cape Sebastian and Crescent City, and off-shore hydrography at Crescent City Reef; to measure a base-line and continue the triangulation of the Strait of Fuca, and the topography and hydrography of Puget Sound and the adjacent waters; to continue the reconnaissance survey of the coast and islands of Alaska, with observations of the tides and currents, and the requisite astronomical and magnetic observations; to continue field-work for description of the coast and verification of the Coast Pilot of the coasts of California, Oregon, Washington Territory, and Alaska Territory; to continue the organized system of magnetic observations required for a complete magnetic survey, and to run lines of levels connecting points in the main triangulation with the sea-level.

OFFICE-WORK.—To make computations of the field observations, including astronomical, geodetic, magnetic, and tidal work; to continue the compilation of the Coast Pilot of the coasts of California, Oregon, Washington Territory, and the Territory of Alaska; to prepare tidal predictions for the year 1883; to continue the publication of topographical and hydrographic maps and charts, and the reductions thereof, and to plot the hydrographic surveys; to continue the drawing and engraving of the general chart of the Pacific coast from San Diego to Point Vincente; to continue the drawing and begin the engraving of the general chart of the coast from Point Concepcion to San Luis Obispo; to complete the engraving of the sailing charts of the Pacific coast in four sheets; to begin that of the general chart of the coast from San Luis Obispo to Point Pinos; to continue the drawing and engraving of the general coast chart from Point Reyes to Mendocino City; to continue the drawing of the general chart of the coast from Point Arena to Cape Mendocino; also, that of the charts of Puget Sound; to provide for the drawing and engraving of additional charts of harbors in Alaska; for materials for drawing, engraving, and map-printing; for electrotyping and photographing, and for instruments and apparatus.

Total for the Western Division, including the Pacific coast, and involving work in four States and eight Territories, will require $245,000.

SURVEYS IN AID OF THE UNITED STATES GEOLOGICAL SURVEY.—This estimate is submitted in pursuance of an understanding with the Director of the United States Geological Survey to the effect that such triangulation and astronomical determination of geographical positions as may be required for the maps of that work can be most advantageously executed by the Coast and Geodetic Survey, which is specially organized for work of that character. The amount asked for that purpose for the fiscal year 1882–'83 is $40,000.

For repairs and maintenance of the complement of vessels used in the Coast and Geodetic Survey will require $40,000.

For continuing the publication of the records of observations made in the progress of the Coast and Geodetic Survey will require $8,000.

For general expenses of all the work, rent, fuel, for transportation of instruments, maps, and charts, miscellaneous office expenses, and for the purchase of books, maps, and charts, will require $32,500.

### OBITUARY.

After a long and busy life devoted to scientific pursuits, Prof. BENJAMIN PEIRCE, consulting geometer of the Coast and Geodetic Survey, died at his home at Cambridge, Mass., on October 6, 1880.

Benjamin Peirce was born at Salem. Mass., April 4, 1809. He was fitted for college under the instruction of Nathaniel Bowditch at Andover, and entered Harvard in 1825, immediately evincing a remarkable talent for mathematics. In 1829 he graduated, and shortly afterwards he accepted a position as teacher of mathematics in Round Hill School at Northampton.

In 1831 he returned to Cambridge to fill the position of tutor of mathematics in that university. He was made university professor of mathematics and natural philosophy in 1833, and Perkins professor of astronomy and mathematics in 1842.

Professor Peirce was appointed Superintendent of the Coast Survey at the death of Prof. A. D. Bache in 1867. Frequently, during many years previous, Professor Peirce had been called upon to assist in matters connected with the Survey, and the knowledge thus obtained, of the objects and general scope of the work, enabled him to assume this important position with an intelligent appreciation of its duties and responsibilities.

During the civil war the regular work of the Survey had been in a great measure suspended. The organization had been preserved merely because it formed a valuable adjunct to the land and naval forces, but the survey of the coast had made but little progress. The first work of the new Superintendent was to arrange for the continuation of the Survey according to the plans laid down and the principles already formulated by his predecessor. It was not long, however, before the influence of his genius and originality, already acknowledged in the highest branches of scientific research, began to be apparent in the conduct of this national work. The extension of the survey of the coast to a great geodetic system, stretching from ocean to ocean, although it had been remotely contemplated by his predecessor, was first actually commenced by Professor Peirce, thus laying the foundation for a general map of the country entirely independent of detached local surveys. With this object the great diagonal arc was extended from the vicinity of Washington to the southward and westward along the Blue Ridge, eventually to reach the Gulf of Mexico near Mobile. He also planned the important work, now in active progress, of measuring the arc of the parallel of 39° to join the Atlantic and Pacific systems of triangulation; and for determining geographical positions in States having geological or geographical surveys in progress. To him also belongs the honor of having proposed to Congress this plan for the extension of the Survey to a geodetic survey of the whole territory of the United States.

Professor Peirce, while Superintendent, took personal charge of the American expedition to Sicily to observe the eclipse of the sun in December, 1870; and for the transit of Venus in 1874 organized two parties from the Coast Survey, one to observe at Chatham Island in the South Pacific Ocean, the other to observe at a station in Japan.

As soon after the war as vessels and officers could be had, he renewed operations for deep sea soundings, and gave his earnest support and assistance to all scientific work in any way related to the Survey.

In the ordinary routine of administrative details, Professor Peirce relied on officers of the Survey having large practical experience in regard to its methods and processes; yet he carefully saw that the work advanced in accordance with his views.

After his retirement from the Superintendency in 1874, in order that the Survey might continue to have the benefit of his great mathematical knowledge, he accepted the honorable position of consulting geometer, exercising a general supervision over the scientific portions of the work.

Professor Peirce had been since 1849 consulting astronomer of the American Ephemeris and Nautical Almanac, and for many years he directed the theoretical part of the work. In 1855 he was entrusted with the organization of the Dudley Observatory. He received the degree of LL. D. from the University of North Carolina in 1847, and from Harvard University in 1867. He was elected an associate of the Royal Astronomical Society of London in 1849, and a member of the Royal Society of London in 1852. He was made president of the American Association for the Advancement of Science in 1853 (the fifth year of its existence), and was one of the original members of the National Academy of Sciences. He was also a member of the Royal Societies of Edinburgh and Göttingen, and honorary fellow of the Imperial University of St. Vladimir at Kiev.

Of the published mathematical writings of Professor Peirce, it may be said that they rather indicate the scope of his intellect than give an adequate idea of the vast and intricate labors with which his mind was constantly occupied. Much that he produced was never put into suitable form for publication, and many of his papers that were finally given to the world were merely the condensed results of successive steps in a wide field of original research. Yet he was the author of many works of the highest scientific value, notably his work on analytical mechanics and his Linear Associative Algebra, besides many text books on mathematics and physics, and separate articles on various subjects. He wrote in a style lucid, concise, entirely free from conventionality, and marked by a wide range of thought.

Although his mathematical work claimed the greater part of his attention, he yet found time for exhaustive studies of kindred topics. In physics, astronomy, mechanics, and navigation his labors are marked by valuable discoveries and new applications of known principles; and his interest extended equally to logic and metaphysics, to geography and geology, and even to botany and zoölogy. In fact nearly all branches of scientific inquiry were enriched by his labors, and in all he displayed the same profound knowledge and bold originality, combined with keen intuition and great force of intellect.

During the year the Survey has suffered the loss of a most accomplished member in the death of Assistant A. M. HARRISON.

Mr. Harrison had been for some years in failing health, but not without hopes of amelioration. He was seized with an attack of pneumonia at his home at Plymouth, Mass., and died, after an illness of a few days, on January 11, 1881, in the fifty-second year of his age.

Mr. Harrison was born at New Haven, Conn., May 27, 1829. His employment in the Survey, commencing December 15, 1847, extended with little intermission over a period of more than thirty years, devoted to active work in field and office. In the field he was engaged chiefly in topography, for which he early displayed a special aptitude. His skill and accuracy, as well as his great industry, are evidenced by the many admirable topographical sheets that bear his name. Mr. Harrison was also possessed of literary talents of a high order. During the last years of his life he was occupied in the preparation of a history of the Plane Table. This task, peculiarly fitted to his tastes, was nearly accomplished at the time of his death.

In personal character Mr. Harrison was marked by refinement and culture, a genial temperament, and warm affections, and his rare social attractions won for him many warm and sincere friends.

# PART II.

The geographical arrangement of the abstracts which follow is the same as that observed in previous reports, namely: Southward along the Atlantic coast, following the inlets and rivers from their mouths towards their heads; westerly along the Gulf coast, following the courses of inlets and rivers towards their heads; northward along the Pacific coast from the southern boundary of California, and including at the north the Territory of Alaska; and in the interior, according to sectional arrangement, from east to west. On the Atlantic coast the deep-sea work in the Gulf Stream is noticed under the head of Section VI, and on the Western coast special magnetic operations to the southward of the southern boundary of California are included under the heading of Section X.

## SECTION I.

### MAINE, NEW HAMPSHIRE, VERMONT, MASSACHUSETTS, AND RHODE ISLAND, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS.

*Topography of Dyer's Neck and Petit Manan Point, coast of Maine.*—The topography of Dyer's Neck and Petit Manan Point, coast of Maine, was assigned in June, 1880, to Assistant H. G. Ogden, who early in July proceeded to Sullivan, Me., and organized a party for the work. The sheet embraces the two peninsulas named, which are separated by Dyer's Bay. The shores are generally rugged, broken with coves bare at low water, densely wooded, and offering few commanding positions. This necessitated much cutting. Two prominent points appear on the sheet, Eagle Hill, on Dyer's Neck, and Pigeon Hill, at the head of Petit Manan Point; the latter is three hundred and eight feet in height, the greatest elevation reached. On the extreme end of Petit Manan Point, and for a mile or more on the shores of Dyer's Bay and Pigeon Hill Bay, a "sea-wall" has been formed by natural action of well-worn stones, ranging in size from pebbles to bowlders, but generally of the dimensions of cobble-stones. The interior slope is quite steep, and in some places reaches a height of six or seven feet. Similar natural walls of sand have been noticed on the shores of the Gulf of Mexico, but on the New England coast such formations are rare.

Subassistant Vinal assisted in the work of the party until October 1, when he was detached for work on the coast of Florida. Field-work was steadily prosecuted until the end of October, when, the sheet upon which he had been engaged being completed, Assistant Ogden disbanded his party. Subsequently he was assigned to the charge of the Engraving Division of this Office. The statistics of the work are as follows:

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|---|---|
| Shore-line surveyed (miles) | 51 |
| Roads (miles) | 24 |
| Area of topography (square miles) | 20 |

*Topography of Frenchman's Bay, Me.*—In the latter part of July, Assistant A. W. Longfellow took the field for the continuation of the topography of the coast of Maine. Work was begun near Lamoine on July 27 upon the sheet commenced during the preceding season, and was continued, with slight interruptions by fog, until August 12, when the sheet was completed, and a satisfactory connection made with the work of Assistant Hosmer on Skilling River. The party then removed to Sullivan, Me., for the survey of the shores and upper heads of Frenchman's Bay. Work in this locality was commenced August 16, and continued, whenever the weather would permit, until September 6. The party then proceeded to Franklin, at the head of Frenchman's Bay, at which locality the work was prosecuted until November 25, when the sheet was completed, and the party left the field.

Mr. Bion Bradbury, jr., was attached to the party as extra observer. The statistics of the work are as follows:

| | |
|---|---|
| Shore-line surveyed (miles) | 43.80 |
| Streams and ponds surveyed (miles) | 28.90 |
| Roads surveyed (miles) | 65.86 |
| Area of topography (square miles) | 29 |

*Hydrography of the coast of Maine, near Mount Desert.*—At the commencement of the year Lieut. S. M. Ackley, U. S. N., Assistant, Coast and Geodetic Survey, with the party on board the schooner Eagre, was engaged in a survey of the Penobscot River between Hampden and Winterport. Hydrography was completed in that locality on July 6, and the party was transferred to the Bagaduce River for a survey of its headwaters. On the completion of this work the hydrography of Jordan River was taken up and finished; thence the party proceeded to Skilling River and surveyed the hydrography of that locality and a portion of Frenchman's Bay. Work for the season was concluded with a survey of Franklin Bay, above and including Sullivan Falls.

The general statistics of the season's work are stated as follows:

| | |
|---|---|
| Number of soundings | 21,084 |
| Angles measured | 5,146 |
| Miles run in sounding | 359½ |

The very irregular forms of the different bodies of water render difficult a correct estimate of the number of square miles covered by the hydrography.

In general the season was very favorable for the execution of hydrographic work, but some time was lost in going to and from the different localities of work. Some inconvenience was also experienced in obtaining a supply of fresh water, which in Frenchman's Bay could only be obtained at the Bar Harbor Water Works, owing to the drying up of the springs and wells.

The steam-launch Sagadahock was used during the season in the execution of hydrography.

The officers attached to the party were Lieut. H. T. Monahon, U. S. N.; Master Frank E. Sawyer, U. S. N.; and Ensign Warner H. Nostrand, U. S. N., all of whom rendered efficient service in connection with the work of the vessel.

During the season Lieutenant Ackley examined and reported on the location for a buoy in Mill Creek Reach, Penobscot River, Me.

*Tidal observations.*—A permanent station for securing a long series of tidal and meteorological observations for the special uses of the survey, and also for scientific purposes, was established at North Haven, off the coast of Maine, in January, 1870, and put in charge of Mr. J. G. Spaulding, who has kept up a very complete set of records to the present time. An excellent self-registering tide-gauge has been used, which is provided with a very efficient heating apparatus to protect it from ice in winter. This has always worked well, even in the coldest weather, and has enabled the observer to secure an almost perfect series. When a short stoppage for repairs becomes necessary, hourly readings are made on a staff-gauge. The station being on an island jutting out into the great Bay of Maine, and near to deep water, seems to be one of the best that has been occupied for making such observations, and, if the series can be kept up successfully a few years longer, it will doubtless satisfy all expectations in regard to it.

*Hydrography of Rockland Harbor, Muscle Ridge Channel, and Skilling's River, Me.*—The party under charge of Lieut. H. G. O. Colby, U. S. N., Assistant, Coast and Geodetic Survey, with the schooner Eagre, having been assigned in March to work on the coast of Maine, arrived at Rockland in the latter part of May, and at once commenced a complete hydrographic survey of Rockland Harbor, the soundings being referred to a tide-gauge temporarily established at that locality. At the close of the fiscal year this survey was nearly completed.

Lieut. H. T. Monahon, Master Frank E. Sawyer, and Ensign Warner H. Nostrand, U. S. N., were attached to the Eagre, and performed efficient work in connection with the hydrography. The combined statistics of the completed work are as follows:

| | |
|---|---|
| Number of soundings | 12, 878 |
| Miles run in sounding | 181. 5 |
| Angles measured | 1, 261 |

*Triangulation of New Hampshire.*—The geodetic station on Mount Washington, marked and partly observed upon before the large hotel and other buildings on the summit were erected, has been of late years so entirely hidden from view that observations for its connection with the triangulation of New Hampshire and of Maine could only be effected by means of an eccentric signal or heliotrope either on the roof of the hotel or of the old Tip-Top House. Finally, the scheme having actually surrounded Mount Washington, the time arrived when it became necessary to occupy the point for the purpose of measuring the previously concluded angles. A tripod over the station to hold the largest theodolite, and a close tower for the protection of the tripod, both higher than the surrounding buildings, was the only plan that promised to secure the necessary command of the horizon, and stability during high winds.

Through the instrumentality of Prof. E. T. Quimby, Acting Assistant, Coast and Geodetic Survey, the interest and generosity of Mr. Walter Aiken were enlisted in the cause, and at his expense, after due consideration of all the objects to be accomplished, the tripod and tower were erected, and were ready for occupation by the middle of August.

From July 1 to the date last mentioned, Professor Quimby was employed in co-operating with Mr. Aiken, and in superintending the execution of the plan agreed upon. The height and other dimensions of the two structures are fully given in the season's report of Professor Quimby.

From the middle of August to October 1, at which date the hotel was closed, and winter had set in, every hour of observing time was improved. One thousand repetitions were secured, and also three hundred pointings by using the theodolite as a position instrument. The station, however, was not completed. Mr. Aiken, who is one of the proprietors of the summit, has expressed his willingness that the tower should stand as long as it is needed for the survey.

After leaving Mount Washington Professor Quimby re-erected certain signals to be observed on from Gile Hill, in Vermont, that being one of the stations of the quadrilateral connecting the astronomical observatory of Dartmouth College with the work of the Coast and Geodetic Survey; and by November 3 the desired measurements at Gile Hill, consisting of seven hundred and fifty pointings, were obtained.

*Triangulation of Vermont.*—Prof. V. G. Barbour, Acting Assistant, Coast and Geodetic Survey, commenced field-work in Vermont early in July. His first operation was to erect signals at ten of the mountain stations selected by him to be observed upon by the party of Assistant R. D. Cutts, then occupying the primary station of Potato Hill. By this co-operation of the two parties angles were measured at the primary station which will save considerable time and expense in the execution of the Vermont scheme. The necessary reconnaissance, marking of points, setting up of signals, and the clearing away of obstructions to intervisibility, consumed the month of July.

Between August 6 and September 22 the two stations of Herrick and North East Mountain were occupied and completed. At the former five secondary and seventeen tertiary points were observed upon, and at the latter, four secondary and five tertiary points. Field statistics:

| | |
|---|---|
| Signals erected | 10 |
| Angles measured | 31 |
| Horizontal directions observed | 834 |
| Vertical angles | 504 |

The party was disbanded on September 23, and on the 25th the camp equipage was stored at the foot of Styles Mountain, preparatory to work at that station next season.

*Primary triangulation in Vermont.*—At the commencement of the year, as mentioned in the last Annual Report, Assistant R. D. Cutts was engaged in occupying the station Potato Hill in Vermont, heliotropers being posted, on account of the length of the lines, at Bald Ledge and Cube in New Hampshire, at Mount Mansfield in Vermont, and at Bigelow, Blueberry Hill, Cheever, and Prospect Mountain in New York.

The weather at Potato Hill during the month of June and July was characterized by heavy storms, with intervening days of unusually clear weather, favorable for observing. Observations were satisfactorily completed at this station by July 24, and the party was moved to the foot of Blueberry Hill, arriving there on July 30. Between that date and August 6 a winding path was cut two miles to the summit, the hill slopes being too steep to admit of a direct course. By the 13th camp was pitched at the summit ready for observing. Owing to unfavorable conditions of the atmosphere resulting from a long drought and extensive forest fires, the latter in one instance destroying an important tripod signal, the work of observing was much impeded. On September 20, there being no improvement, the party was transferred to the station Cheever, one of the Lake Champlain triangulation points. By the 27th the observations at Cheever were completed, and the difference of level (370.35 feet) between the station and the level of the water of the lake on September 25 was determined by the spirit-level, the line being leveled forward and back. On the 30th of September Field's Hill was occupied, and by October 5 the observations were finished.

The line selected for the southern connection of the lake, Cheever–Fields Hill, was the longest of the Lake series, running quite close to the base on Crown Point, and including the astronomical azimuth observed some years ago at Cheever Station. Thus an interesting comparison of results was obtained, one set derived from Mounts Tom and Monadnock and the primary base apparatus, and the other from the lake triangulation and the secondary or sliding contact apparatus.

From Mount Tom to Fields Hill the distance is about one hundred and thirty-five miles.

The length of the line Fields Hill–Cheever, as determined by Assistant Cutts without station or figure adjustment, is 22,403$^{\text{m}}$.5.

The same line as given by the computing division upon a recomputation of the lake quadrilateral is 22,403$^{\text{m}}$.5.

The leveling executed at Cheever was done for the purpose of determining how close the trigonometrical leveling from the vicinity of Troy, N. Y., could determine the height of the water of Lake Champlain above the mean tide of the ocean. Whenever the height of the lowest stage of water in the lake shall be determined by means of a line of spirit leveling from the bench-mark at Lansingburg, near Troy, a comparison of the results may be made, and the trigonometrical leveling between the two well ascertained heights may be adjusted, as in the case of a triangulation between two measured bases.

The height of Lake Champlain, as given by Mr. Verplanck Colvin, superintendent of the Adirondack Survey, in his report for 1879, is 99.3 feet. This result was obtained from the records of the engineers in charge of the canal from Troy to Whitehall.

The trigonometrical leveling makes the height above mean tide vary from 93.4 feet at extreme low water to 103.5 feet at extreme high water. There are at present no data by which the exact height at any particular stage of the water can be determined.

When the occupation of Fields Hill was completed the party was disbanded, and Assistant Cutts, after a rapid preliminary reconnaissance for a further extension of the scheme, returned to the office at Washington. The statistics for the season are as follows:

| | |
|---|---|
| Directions observed | 66 |
| Pointings | 1,424 |
| Readings | 8,544 |
| Differences of heights | 25 |
| Zenith distances | 365 |

*Hydrography of Pickett's Ledge, entrance to Salem Harbor, Mass.*—Before commencing work on the coast of Maine, Lieut. H. G. O. Colby, U. S. N., Assistant Coast and Geodetic Survey, with the hydrographic party on board the schooner Eagre, proceeded to Pickett's Ledge, at the entrance of Salem Harbor, Mass., and made a complete hydrographic development of that ledge, soundings being taken at frequent intervals over the whole area of the shoal. These were referred to a temporary tide-gauge at Walnut Cove, and thence to a permanent bench-mark established for the purpose. Tides were also observed at Boston, Mass., during the execution of the soundings. Work in this locality was included between May 4 and May 12. Thence the party proceeded to Rockland Harbor, as noticed in a previous abstract.

The following officers of the Navy were attached to the Eagre and assisted in the work: Lieut. H. T. Monahon, U. S. N.; Master Frank E. Sawyer, U. S. N.; and Ensign Warner H. Nostrand, U. S. N.

*Tidal observations at Providence, R. I.*—The self-registering gauge loaned in 1872 to the engineers of the city of Providence, R. I., has been kept running by them a large part of the time since then, in connection with their surveys relating to various local improvements being made. Their observations from the beginning to January, 1878, have been received, and they have been kept supplied with paper and blank forms for the curves and other records which they have engaged to continue and transmit as soon as they can conveniently. Valuable results have been deduced from these observations, and others may confidently be expected.

## SECTION II.

### CONNECTICUT, NEW YORK, NEW JERSEY, PENNSYLVANIA, AND DELAWARE, INCLUDING COAST AND SEA-PORTS, BAYS AND RIVERS.

*Topography and Hydrography of the south coast of Long Island.*—The survey of the bays and islands of the south coast of Long Island, from the termination of his work of the preceding season to Fire Island, was taken up by Assistant J. W. Donn at the beginning of July, the schooner Scoresby being assigned for the use of his party.

Previous to commencing the regular work of the season a survey was executed of Cornell's Creek, in Jamaica Bay, a work which was attended with some difficulty, owing to the inaccessibility of the ground. After the shore line of the creek had been run, distances on each side were measured and marked at proper intervals, and a hempen cord, knotted for each three feet of its length, stretched across from each stake to its opposite. At each knot the depth of water was obtained with a sounding pole marked in feet and tenths. A temporary tide-gauge was erected at the Club House wharf, to which the soundings were referred. When this work was completed, Assistant Donn was occupied for a few days in placing upon the topographical sheet of 1879 the extensive improvements made since that date at Long Beach, including the railroad extending from the Beach to East Rockaway, a distance of four miles. The party was then transferred to New Inlet, and an anchorage was found in the vicinity of Freeport. In the meanwhile the topographical work was going on, and by the close of July nearly all of the marsh and beach work west of the main channel of New Inlet was finished. The hydrography was commenced in August and steadily continued until the close of the season. Some difficulty was experienced in this work, owing to the fact that soundings could not properly be taken except during the interval between two-thirds flood and one-third ebb-tide, so that rarely more than four hours' work could be done in the course of each day. The various bays, with their numerous marshy islands, rendered it impossible during low-water to get a boat to firm ground. The Scoresby was moved about the middle of September to an anchorage near Babylon, from which work was prosecuted until the 26th of October. By that date all the shore line and islands were finished, the work connecting on the north side of Great South Bay with the work of Assistant Iardella, and on the south with that of Assistant Hosmer. The soundings being completed by the 1st of November the vessel sailed for Baltimore.

During the execution of the soundings tidal observations were recorded at Babylon, Amityville, and Jones Inlet. The reduction of soundings, a rather difficult task owing to the great difference between the maxima of tides at the inlets, at the heads of channels, and in the broad bays, has been successfully treated in the Hydrographic Division of this office. The following statistics show the work accomplished during the season:

| | |
|---|---|
| Topography: | |
| Shore line of beaches and islands (miles) | 430 |
| Area (square miles) | 48 |
| Hydrography: | |
| Number of soundings | 26,542 |
| Number of angles measured | 2,020 |
| Miles run in sounding | 291 |

During the latter part of the year Assistant Donn has been employed in a survey of the District of Columbia, which will be noticed in its proper place under the head of Section III.

*Tidal observations.*—The self-registering tide-gauge at the depot of the New Jersey Southern Railroad, on Sandy Hook, N. J., has been kept running almost continuously since it was set up, in 1875, by Mr. J. W. Banford. Being the general manager there he has great facilities in keeping things in order, and has generally been successful. It is a rather difficult place, however, to keep up continuous observations, partly on account of the roughness of the water, especially during storms, and partly on account of the ice in winter. The fixed parts were strongly braced and seem to have stood well, but there is necessarily much friction of the working parts of the apparatus which necessitates frequent repairs. A good many tides were lost during the severely cold spells of last winter, and it is very desirable that something be done to make the record more complete in future. The scale has been recently changed from one-eighth to one-tenth in order to prevent the defects at extreme high and low waters, the range of the tides being somewhat greater than had been anticipated, especially when the effects of storms are added, which are quite large at this place.

*Special operations.*—The work of securing and re-marking primary trigonometrical stations in the Hudson River scheme of triangulation having been assigned at the outset of the fiscal year to Assistant F. H. Gerdes, the early part of July was spent in gathering the necessary records and instruments, and directing the construction of granite monuments and iron screw-piles for station marks. Assistant Gerdes was not able to commence this work at that time, owing to the necessity for re-marking triangulation points in the vicinity of Philadelphia, needed in the re-survey of the Delaware River, to which duty he was transferred, as will be noticed in an abstract which follows. In June he again took the field, and at the close of the year was engaged in the verification and re-marking of the Hudson River points.

*Topography of the Hudson River.*—In previous seasons the topography of the Hudson River had been advanced by Assistant H. L. Whiting as far as the vicinity of Highland Falls, on the west bank. In July work was resumed in this locality on a scale of $\frac{1}{10000}$, and carried northward towards West Point. Five subsidiary points in the triangulation, determined during the season by Mr. C. H. Van Orden, Aid, were used as stations from which to extend the plane-table work. These points served also as a basis for the large scale survey of the immediate vicinity of West Point.

Owing to the great detail and intricacy of the work, caused by the dense woods and broken nature of the ground, the system pursued by Mr. Whiting in the execution of the topography was primarily to complete detached portions of the survey at localities from which the intervening portions could be overlooked. The physical features on this bank of the river, although diversified, are more decided than those on the east bank, the hills and peaks more distinctly separated, and the valleys between better defined. Hence the importance of securing at the outset commanding positions, from which the intermediate details could be filled in.

The river shore, with its marginal topography, was completed from the boundary of the government land near Block House triangulation station, southward to include Cozzens's Dock and the older landings below at Benny Haven's. It includes also the village of Highland Falls, the valley and the creek, which was taken as the best natural boundary between the $\frac{1}{10000}$ sheet and the adjoining one to be projected hereafter. This valley and creek and the main road along the river bank were surveyed back for a distance of about two miles to the point where the road branches, one fork forming the old road to Newburg, one the "Point road," so called, and the third fork leading over Crow's Nest Mountain to Cornwall. This last road is named by Mr. Whiting as the best inland westerly boundary for the $\frac{1}{10000}$ work of the general river topography.

By August 20 work was nearly completed to the limits of the large scale ($\frac{1}{4800}$) sheet of West Point, and the topography on this sheet was at once commenced. Work was steadily prosecuted until the 7th of December, when the party was disbanded. The scale of $\frac{1}{4800}$ was sufficiently large to show close details, and rendered necessary the determination of every station and the measurement of every line and offset within the limit of error of one meter, a discrepancy of that extent being quite perceptible. Each station was brought into perfect agreement and coincidence with every other from different points and bases, a task involving much labor. Along the more hidden and intricate banks forming the Point the numerous paths enabled the topographer to sketch the contour lines with sufficient accuracy. All levels were referred to the plane of mean high-water at the Coast and Geodetic Survey bench-mark at West Point, from which also reference bench-marks were determined by numerous observations. Every detail admitting of representation is shown upon the sheet.

Mr. W. C. Hodgkins, Aid, was attached to the party of Assistant Whiting during the season, and rendered efficient service in the topography.

Much interest in the work was manifested by the officers of the Army stationed at West Point, who afforded every facility and free use of all data in their possession pertaining to the survey.

*Reconnaissance.*—As mentioned in the last Annual Report, a reconnaissance was made in 1879 by Assistant S. C. McCorkle for the extension of a scheme of primary triangulation westward from Lake Champlain. The practicability of the scheme thus developed not being in all respects assured, Assistant C. O. Boutelle was directed towards the close of the fiscal year 1880 to take the field for the continuation of this work.

In June and July Assistant Boutelle examined the country west of Black River and between it and Lake Ontario, and found it to be generally a plain, sloping towards the lake, with no points sufficiently elevated above the general level to be seen from the surrounding region except by the use of high tripod signals. The summits Pen Mount (about one thousand eight hundred feet above the sea), Steuben Township, Oneida County, and Gommer's Hill, in Turin Township, Lewis County, were found to rise above all others, and were, therefore, selected as essential points in the scheme. These stations overlooked the wilderness, where there was a probability of finding points that would overlook the stations Prospect–Marcy in the scheme of Assistant Cutts. Westerly from Gommer the country appeared nearly level and densely wooded, necessitating the use of high tripods. From Pen Mount and elevations in the adjacent region the entire range of mountains south of the Mohawk River was visible.

In view of these facts, Assistant Boutelle proceeded to lay out a scheme to the southward of the original scheme, and based upon the line Prospect–Helderberg, making use of only the southern stations in the original scheme, and selecting new points upon the principal crests south of Mohawk River. These points were so located as to be available in the future for extending the primary triangulation southward towards the Pennsylvania line and northward towards the Saint Lawrence. In projecting this scheme much assistance was received from the primary triangulation laid out and partly executed by the New York State survey, under the direction of Mr. James T. Gardner. Work was continued until the latter part of October, when the weather becoming too severe for field operations the party was disbanded. At that time observations had been completed at Pen Mount, and were partially completed at Tassel Hill, about one thousand nine hundred feet above the sea.

The statistics of the work are as follows:

At Pen Mount six primary and two secondary stations were observed upon in thirty-three series each upon primaries, and sixteen series each upon secondaries. The reference point was Star Hill signal of the New York State survey, distant 2.44 miles. Double zenith distances of the reference point were observed upon four days with the vertical circle. Micrometer differences of level were observed on three days between the reference mark and all the other stations. Observations were also made for value of eye-piece micrometer. At Tassel Hill geodetic observations were completed upon Pen Mount, Otsego, Fenner, and Florence, primary stations, and upon Star and Barto, secondary stations. Observations were also made for latitude and micrometer differences of level.

Field-work was resumed in June, 1881, when a reconnaissance was made to determine the intervisibility of the line Otsego–Rafinesque. Observations were resumed at Tassel Hill on June 20, and were still under way at the close of that month. The weather during June was generally unfavorable for field operations.

Mr. Thomas P. Borden was attached to the party as aid during this season, and Mr. J. B. Boutelle as extra observer.

*Primary triangulation in New York.*—As noticed under the head of Section I, Assistant R. D.

Cutts had occupied during the fall of 1880 the two stations, Blueberry Hill and Cheever, in New York, being points in the Lake Champlain scheme of triangulation. He had also made a reconnaissance of the country between Mount Mansfield and the boundary line, including the adjoining portion of Canada, in the spring and fall of the same year; and with the data thus supplied, a scheme for the triangulation, extending as far north as Montreal, had been laid out and adopted. In the execution of this scheme, starting from the main stations last occupied, the first work in order was the erection of tripod signals at the new points selected, and the clearing of summits sufficiently to command the horizon. Part of this work was executed in May by Prof. V. G. Barbour, who volunteered his services for this duty.

Early in June observations were commenced by Assistant Cutts from the summit of Bigelow Mountain, heliotropers being posted at Highgate and Bellevue stations. Fifteen signals were observed upon, and their directions determined by three hundred and seventy pointings, each pointing composed of six readings of the micrometer-microscopes.

The differences of elevation between Bigelow and seven principal stations were determined by thirty-nine series of double zenith distances, each series consisting of five repetitions.

The occupation of Bigelow station was completed two days after the close of the fiscal year.

In reference to the comparison between the geodetic and astronomical azimuths of the station on Prospect Mountain, N. Y., Assistant C. A. Schott, Chief of the Computing Division, remarks that the difference is such as to indicate attraction by the mass of the Adirondack Mountains.

*Longitude observations at Cape May, N. J.*—Towards the close of April Assistant G. W. Dean, with Mr. F. H. Parsons, Aid, proceeded to Cape May, N. J., and there erected an astronomical observatory for telegraphic longitude purposes. Similar observatories were also erected at other points, which will be mentioned under the proper sections. During these preliminary operations Assistant Edwin Smith, with Mr. Carlisle Terry, jr., as Aid, was engaged in determining azimuth at the base lines at Greenville, Miss., and Louisville, Ky. Observations for this purpose were finally completed on April 15. Mr. Smith then reported at this office.

The longitude instruments were not ready until April 26. They were then immediately sent to Assistant Dean, at Cape May, and, on the following day, another set was placed in position at the Naval Observatory. Subassistant C. H. Sinclair reported for duty to Assistant Smith on April 27.

Continuous bad weather prevented the commencement of longitude exchanges until May 4. Longitude determinations between Washington, D. C., and Cape May, N. J., were made on the nights of May 4, 7, 9, 10, and 11, when the observers changed places, Assistant Dean coming to Washington, and Assistant Smith proceeding to Cape May. Similar determinations were then made on May 20, 24, 25, 26, and 27. At Cape May latitude observations were also made by Mr. Smith, with transit No. 6, on the nights of May 13, 16, 20, 24, and 27.

The party left Cape May on the 28th. Its further operations are detailed in Sections III and XIV.

*Topography and triangulation near Cape May, N. J.*—Having been directed in June of the preceding year to resume the topography in the vicinity of Cape May as soon after the commencement of July as possible, Assistant C. M. Bache was occupied during the early part of that month in organizing his party and fitting the barge Beauty for the season's work. After completing these preparations, and moving the barge from her winter quarters to a central location, the necessary signals were erected, and on July 26 the plane-table survey was commenced, beginning at the upper end of the sheet completed during the previous season and working northward. From that date the work was steadily continued until November 17, when operations were closed, the party discharged, and the barge laid up for the winter.

Mr. E. L. Taney was attached to the party, as Aid, and rendered useful assistance in the topography. The statistics for the season are appended:

| | |
|---|---|
| Shore-line (miles) | 145 |
| Roads (miles) | 34. 2 |
| Area (square miles) | 17. 25 |

The work executed extends from Turtle Gut Inlet to Hereford Light.

The work of establishing points for the topographical survey was resumed in June by Assistant C. M. Bache; the triangulation extended by the close of the season from the stations Two-Mile Beach–Physic to the stations Hereford Light, Hot, Cresse, and Eldridge, and observations were partially completed preparatory to taking up the topography.

The work not requiring an extreme degree of accuracy, no attempt was made to secure quadrilaterals, but the scheme was extended as a chain of simple triangles.

*Hydrography of Delaware Bay.*—Lieut. E. B. Thomas having fitted the steamer Endeavor, at New York, for hydrographic work, arrived in Delaware Bay on July 14, and immediately commenced the erection of signals, the lumber for which was procured at Delaware City.

The first work of the season was the survey of the main ship channel from Ship John Light towards Brandywine Shoal Light, and of that portion of the bay to the eastward of Ship John Light, including an examination for a reported lump to the southward of the Fourteen Feet Bank. Following this the position was determined for a proposed light-house near Lewes, Del. A detailed survey was then made of the lower end of Joe Flogger Shoal and of the Fourteen Feet Bank for the purposes of the Light-House Board. Work was concluded with the survey of Cape May channel to the end of Brandywine Shoal and the survey of Brown Shoal. At the end of October the Endeavor was laid up at the League Island navy-yard.

In reference to these several pieces of work Lieutenant Thomas reports, in substance, as follows:

The five-foot spot marked on the published charts, on the line joining Ship John and Cohansey lights, does not now exist.

The depth of water on both ends of Joe Flogger Shoal has increased considerably since the last survey.

The shoal spot reported to the Superintendent of the Coast and Geodetic Survey by the master warden of the port of Philadelphia as existing on the following bearings, Fourteen Feet Bank light-ship bearing north and Brandywine and Cape May lights in range, could not be found after a thorough search for a considerable distance around the place indicated. The conformation of the bottom and the prevailing tidal currents render the existence of such a shoal impossible. The least water found on the Fourteen Feet Bank was a single sounding of eighteen feet. The position of the buoys required redetermination and the "Buoy of the Middle" was found to be too far to the westward of the center of the channel.

In locating the site of the proposed light-house near Lewes it was found necessary to take some soundings off the shoals at the mouth of the bay. From these soundings it seems that McCrie's Shoal has shifted its position quite half a mile to the northward since the old survey. In order to show the extension of the shore line at Cape Henlopen and its altered relation to the beacon light, Lieutenant Thomas took a number of sextant angles along the beach and sketched the shore line in his projection. He also reported that the shoals off Cape May have so greatly changed that a resurvey of them is rendered very desirable.

The naval officers attached to the vessel were Lieut. Hugo Osterhaus, Master Chas. J. Badger, Ensign William H. Allen, with Mr. E. H. Wyvill as recorder. To their zeal and intelligence much of the success of the season's work is due. The statistics of the work are appended:

| | |
|---|---|
| Miles run with soundings | 702⅝ |
| Signals erected | 5 |
| Signals determined in position | 14 |
| Number of soundings | 21,579 |
| Stations occupied | 14 |
| Angles measured | 7,770 |

During the winter season the steamer Endeavor was engaged in work on the coast of Florida, which will be noticed under Sections VI and VII.

*Triangulation of the Delaware River.*—In connection with the topographical and hydrographic re-survey of the Delaware River, for which special appropriations were made by Congress, Assistant S. C. McCorkle was assigned in June to the continuation of the triangulation between the former work of Assistants Sullivan and R. M. Bache. This work, extending from New Castle to Delaware City, was, at the end of June, nearly completed, although to determine the light-houses it will be necessary to occupy two more stations. At that date four stations had already been occupied, and ten points determined in checking these light-houses.

Assistant McCorkle reports that many of the stations erected by Assistant Sullivan were swept away by a gale in 1878, and that it will be necessary to examine and perhaps re-determine several points.

*Topography of the Delaware River.*—The topographical re-survey of the Delaware River, from Fort Mifflin to Chester, was assigned in June, 1880, to Assistant C. T. Iardella. After visiting the field of work and organizing his party, Assistant Iardella commenced the actual work of the survey on July 18, beginning near Fort Mifflin, at the termination of the work executed in 1879 by Assistant R. M. Bache. Thence the survey was continued on both sides of the river as far as the lower end of Chester City.

Since the last survey the shores on both sides of the river were found to have changed but little, but in some of the islands a perceptible change was noticed. Maiden's Islands have changed since the last survey was made, the easterly one having been washed away on the western end, causing a large and long shoal, visible at very low tides. A very perceptible change has also taken place on little Tinnicum Island, that island being nearly three hundred and fifty meters less in extent than formerly, and having long shoals at either end. The effect of this has been to change the channel towards the New Jersey shore, it now being impossible for vessels of deep draft to sail in the inside channel, as at very low tide only six feet of water can be carried over the shoal, which extends from the island side nearly across to the Lazaretto. Improvements have been made at the mouth of Ridley Creek which facilitate navigation. Chester Island was found to have increased in length since the last survey, and to have changed in relation to Chester Island Bar, which twenty years ago was only a sand shoal, but is now an island about three-fourths of a mile long. Both islands are flooded at high water. Raccoon Creek, as is the case with the other creeks, is nearly bare at low water, and steamers can pass through only at high tide.

Subassistant Joseph Hergesheimer was attached to the party of Assistant Iardella from July 18 to September 11, when he was obliged to leave on account of sickness. Work was finally closed on November 16. Field statistics:

| | |
|---|---|
| Shore line surveyed, including wharf line of Chester City, miles | $41\frac{3}{4}$ |
| Roads, including streets of Chester City, miles | $18\frac{1}{4}$ |
| Marsh line, miles | $20\frac{1}{4}$ |
| Bank, miles | $21\frac{1}{4}$ |
| Ditches, miles | $35\frac{1}{4}$ |
| Low water, miles | $24\frac{3}{4}$ |
| Streams, miles | $11\frac{1}{4}$ |
| Railroad, miles | $6\frac{3}{4}$ |
| Area, square miles | $10\frac{3}{4}$ |

Early in April work was resumed on the Pennsylvania shore, joining the completed shore-line of the preceding season at triangulation station Yarnall's. The topography was continued from this point to Grubb's Landing and Taggart's Point, and carried back to the old Baltimore and Wilmington Turnpike as a boundary.

The character of the country in this section is entirely different from that covered by the preceding season's work, there being very little marsh line as compared with that of the New Jersey shore. From Marcus Hook to the westward there is a chain of high hills covered with trees. Some of these hills rise to a height of two hundred feet, and greater heights will be reached as the survey progresses. The statistics of the work to June 30 are as follows:

| | |
|---|---|
| Shore line surveyed, miles | $6\frac{6}{8}$ |
| Low water surveyed, miles | $6\frac{3}{8}$ |
| Bank line surveyed, miles | $3\frac{1}{2}$ |
| Roads surveyed, miles | 22 |
| Streams and ditches | $9\frac{1}{4}$ |

*Triangulation and topography of the Delaware River.*—Before the close of the preceding season Assistant R. M. Bache had made a reconnaissance for the extension of the triangulation along the

Delaware River, between Chester, Pa., and New Castle, Del. At the beginning of July the triangulation between these limits was commenced and steadily prosecuted until its completion on November 22.

The triangulation included determinations of the principal conspicuous objects in Wilmington, and the connection with the position of the former triangulation station at the old Town Hall in that city. The following statistics are reported for the triangulation:

| | |
|---|---|
| Number of stations occupied | 13 |
| Number of sets of observations of six repetitions | 818 |
| Number of concluded angles | 34 |
| Number of sets of observations of two repetitions | 290 |

The topography from Raccoon Island to Penn's Grove was taken up by Assistant Bache on May 26, and at the close of the year was steadily progressing. During the month of June work was retarded by rainy weather. The statistics to July 1 are as follows:

| | |
|---|---|
| Shore-line surveyed, miles | 13. 8 |
| Dikes surveyed, miles | 10. 1 |
| Ditches surveyed, miles | 21. 3 |
| Roads surveyed, miles | 1. 5 |
| Area of topography, square miles | 3. 2 |

*Hydrography of the Delaware River.*—In continuation of the re-survey of the Delaware River, Lieut. H. B. Mansfield, U. S. N., Assistant Coast and Geodetic Survey, having fitted the steamer Arago for hydrographic work, commenced operations on May 3 with the establishment of a tide-gauge and erection of signals preparatory to running lines of soundings in that river. His first projection, extending from the upper end of Little Tinnicum Island to Chester Island Bar, was finished on May 16. From that date until May 25 the party was engaged in office-work, tidal observations, and in running a few lines of soundings. Work was then commenced on a projection extending from Chester Island Bar to the upper end of Marcus Hook. This work being satisfactorily completed on June 15, a third projection from Edgemoor to above New Castle was taken up, and by June 23 the sounding-lines were all finished. The party was engaged in office-work to the close of the fiscal year. The statistics for the season are as follows:

| | |
|---|---|
| Miles run with soundings | $206\frac{7}{8}$ |
| Angles measured | 3, 739 |
| Number of soundings | 20, 054 |

Except on small creeks and shores, which were traversed, all lines of soundings run were sectional, normal to the river, and at an estimated distance of 300 feet apart. Tide-gauges were erected as near the middle of each sheet as possible, and planes of reference carried from sheet to sheet, using the League Island plane as a standard.

Lieutenant Hugo Osterhaus, U. S. N., and Ensign W. H. Allen, U. S. N., were attached to the Arago during the season.

*Hydrography below Fort Mifflin.*—Assistant H. L. Marindin, having been detached from the party of Assistant Henry Mitchell for the purpose of continuing the hydrographic re-survey of the Delaware River, arrived at Philadelphia on April 25, there assumed charge of the schooner Ready, with Ensign C. H. Amsden and E. M. Katz, U. S. N., as assistants, and immediately proceeded to the field of work below Fort Mifflin. Two hydrographic sheets and part of a third were completed by July 1, the statistics of which are as follows:

| | |
|---|---|
| Number of miles run with soundings | 162 |
| Angles measured | 3, 336 |
| Number of soundings | 11, 308 |
| Number of signals rebuilt | 11 |

The limits of these sheets are as follows: From Fort Mifflin to Powder Magazine; from Raccoon Island to Old Man's Creek; from Old Man's Creek to Edgemoor.

Much of the success in the execution of this work is due to the zeal and activity of the naval officers attached to the party, and the efficient aid rendered by them in the hydrographic operations.

On June 21 the vessel sailed for Philadelphia for repairs, which were under way at the close of the year.

*Special operations.*—As previously noted, it was deemed advisable to suspend, at the commencement of the year, the re-marking of primary trigonometrical stations on the Hudson River, preparations for which were well under way, in order that five stations needed in the re-survey of the Delaware River might be recovered and properly secured. These stations were Mount Holly, Yard, Willow Grove, Pine Hill, and Lippincott.

Mount Holly was recovered by Assistant Gerdes, after a long search, and the granite monument placed in position over the center of the cone. It now rests upon a cemented base of bowlders, carried up to a distance of two feet around the granite, in order to hold it firmly in place. At Yard Station the ground had been plowed away, leaving the cone within two feet of the surface, resting upon a large rock. The station was secured by a strong superstructure of masonry, with side walls firmly cemented. The station Willow Grove, situated in the middle of a large field, was not recovered, owing to the damage to growing crops and consequent expense that would have attended the search. The granite monument intended for this station was stored at a hotel in the village of Willow Grove. The cone marking the station at Pine Hill was found without difficulty, and secured as in the case of Mount Holly. The search for Lippincott was unsuccessful.

The stations re-marked are fully described by the records turned into the office by Mr. Gerdes.

*Triangulation in New Jersey.*—Prof. E. A. Bowser resumed the observations at Mount Olive Station on July 1, having previously readjusted the signals at four of the principal connecting stations and erected others at Culver's Gap and Hamburg. Heliotropes were found necessary at High Mount and Culver's Gap. In the month of September an observing tripod twenty-four feet in height was erected at Haycock in order to command a view of Big Rock, both stations being in Pennsylvania, and forming part of the quadrilateral connecting the New Jersey and Pennsylvania schemes. The measurements required at Mount Olive were completed by September 17, and on the 20th the party moved to Haycock. The observations required at Haycock were completed by November 23, and between that date and the 30th some leveling was done from Montana in the direction of Mount Olive. Field operations were suspended November 30. Field statistics:

| | |
|---|---|
| Angles observed | 46 |
| Number of repetitions | 1,616 |

The work was again resumed in May, and at the end of the fiscal year Professor Bowser was engaged in the occupation of Montana Station.

*Triangulation in Pennsylvania.*—The triangulation of Pennsylvania was resumed by Prof. L. M. Haupt, Acting Assistant, on July 1. After posting the heliotropers the station of Wormelsdorf was occupied, and the required measurements completed by July 10. Between that date and the close of the season five additional stations were occupied, either for the full series of observations, or for the verification of those of preceding years. Besides these operations two new stations were established and signals erected, one at Swatara, Lebanon County, and the other near Centralia, Columbia County, Pennsylvania. While at Smith's Gap in October, the weather was so unfavorable that it was found impossible to complete the connection with the New Jersey scheme as was intended. This, however, will be effected next season, when there will be a continuous chain of observed triangles between the geodetic bases of New Jersey and Pennsylvania.

The excellent management of his party and the funds at his disposal enabled Professor Haupt to accomplish a large amount of work during the season, as shown by the following statistics:

| | |
|---|---|
| Stations occupied | 6 |
| Angles observed | 39 |
| Sets of six repetitions | 448 |
| Pointings | 5,376 |

At the close of his report, and in consequence of his proposed resignation of his position as Acting Assistant in the United States Coast and Geodetic Survey, Professor Haupt presents an interesting summary of the progress and results of the triangulation under his special charge, since its inception in 1875, to the date of report. It is a source of regret, on the part of the Survey, that he was obliged, on account of other engagements, to tender his resignation.

Prof. Mansfield Merriman, of the Lehigh University, Bethlehem, Pa., has been recommended by the governor of the State and endorsed by the faculty of his college as a successor to Professor Haupt, and will continue the work in Pennsylvania during the coming fiscal year.

## SECTION III.

### MARYLAND, VIRGINIA, AND WEST VIRGINIA, INCLUDING COASTS AND SEAPORTS, BAYS AND RIVERS.

*Coast Pilot work.*—From July 1 to October 16, Assistant J. S. Bradford was actively engaged in the field, between Montauk Point, Long Island, and Cape Charles, Virginia, in making a personal examination of all the inland waters between those two points, with a view to the preparation of a Coast Directory for small craft. During this time he visited every inlet and point between those localities, and compiled voluminous notes which will be embodied in a new work about to issue.

Additional views being required for the Coast Pilot in the vicinity of Cape Henry, Virginia, Mr. J. R. Barker was directed, early in April, to proceed to that locality, and make the necessary sketches. Assistant Gershom Bradford was instructed to meet Mr. Barker at Fortress Monroe with the schooner Palinurus, then making an examination of the oyster-beds in the Chesapeake Bay, and to afford him transportation to such points as he might deem advisable for his purposes. Mr. Barker arrived at Fortress Monroe on May 3. On the completion of this work, which occupied several days, on account of unfavorable weather, Mr. Barker returned to the office in Washington and the Palinurus resumed her regular operations on the Chesapeake.

During the year Mr. George A. Morrison was employed as writer in copying Coast Pilot materials. He finished a fair copy of Lieutenant Bradbury's elaborate report upon ice-fields on the New England coast, during the exceptionally severe winter of 1874–'75; collated and prepared a general index for Volume II of the Atlantic Coast Pilot; also several indices for the sub-volumes; and marked upon the working charts in ink, changes, corrections, and new information relative to the inland water navigation along the Atlantic coast. He is still engaged in similar work.

*Hydrography north of Chincoteague Inlet.*—Commander E. P. Lull, U. S. N., hydrographic inspector, Coast and Geodetic Survey, organized a party in July and assumed command of the schooner Ready, for the continuation of the hydrography of the inland waters lying along the coasts of Maryland and Delaware, north of Chincoteague Inlet.

The Ready arrived at Franklin, Va., in Chincoteague Bay, on July 20, and preparations for the hydrography were at once commenced. A tide-gauge was established, and a search made to recover points in the triangulation of the coast needed for reference in the survey. A few of these were found, but most of them had been destroyed by the action of the elements. The necessary signals were erected and determined in position, and the work of sounding was then begun. The water being shallow, poles were used for sounding, almost exclusively, the lead and line being resorted to only in the deep places.

The work was continued until September 10, when the vessel, being needed for other work, was removed to Baltimore, Md. The hydrography was extended to a point a little above Snow Hill Public Landing, a distance of twenty miles from the entrance of the bay. Statistics of hydrography:

| | |
|---|---|
| Miles run with soundings | 452.3 |
| Angles measured | 2,549 |
| Number of soundings | 16,455 |
| Tide-gauges erected | 4 |

The following-named officers were attached to the party and rendered valuable aid in the hydrography: Lieut. E. M. Hughes, U. S. N.; Ensign C. H. Amsden, U. S. N.; and W. C. Willenbucher, hydrographic draughtsman.

*Special hydrography.*—The work of investigating the oyster-beds in the Chesapeake Bay, which had been prosecuted with valuable results during the seasons of 1878 and 1879 by Master Francis Winslow, U. S. N., Assistant Coast and Geodetic Survey, was resumed in November, 1880, by Assistant Gershom Bradford, in the schooner Palinurus.

The objects contemplated in this work are, briefly, to ascertain by actual surveys and examinations the location and area of the oyster-beds, their present condition, the approximate quantity of oysters on each, and where deterioration exists, its causes, and their remedy, if such is practicable. The operations of Assistant Bradford have been confined mainly to the location, area, and present condition of the beds, leaving the remaining points as subjects for future study.

Owing to the severity of the winter the party was first employed in gathering general information in regard to the oyster-beds in the Rappahannock River, and relative to the nature and amount of the oyster trade at Crisfield, Md. On February 17 the vessel was moved to Onancock Creek, and an examination commenced of the creeks and eastern shore of the bay, beginning at the southern limits of the work of the preceding season, immediately north of Chesconnessex Creek. Researches were made during the season in the creek just named, in Onancock Creek, and Machotank Creek, Pongoteague Creek, and Butcher's Creek, and the oyster-beds of Onancock Creek were carefully located and investigated. The examination of Hack's Rock, near Woody Island, was in progress and nearly completed when the work was discontinued. The results of these examinations and the methods employed are given in full in the season's report of Assistant Bradford. Much valuable information has been gained, and a quantity of oyster specimens have been turned into the office by Assistant Bradford. These are now the subject of special study at the Smithsonian Institution.

Early in June, Assistant Bradford was directed to make a resurvey of Chincoteague Shoals, in which considerable changes were reported. The vessel was moved to Chincoteague Inlet, and by June 18 the necessary preliminary work of erecting signals was completed and the survey commenced. This work was still in progress at the close of the fiscal year, and the results will be noticed in the next annual report. By June 30 the examination of the outer shoals and their vicinity was nearly completed. The statistics of this work are as follows:

| | |
|---|---|
| Number of signals erected | 5 |
| Number of other shore stations determined | 4 |
| Number of angles measured from shore stations | 217 |
| Number of miles of sounding lines | 151.8 |
| Angles measured for sounding lines | 1,100 |
| Number of soundings | 5,956 |

Mr. W. C. Willenbucher, hydrographic draughtsman, rendered useful service in the party during the hydrographic work.

*Triangulation of the District of Columbia.*—The tertiary triangulation of the northern portion of the District of Columbia, preparatory to a detailed topographical survey of the District, was assigned, at the beginning of July, to Assistant S. C. McCorkle. The southern portion of the triangulation, executed by Subassistant C. H. Sinclair, will be separately noticed.

Assistant McCorkle was engaged in the work of reconnaissance from July 16 until August 11. The work of observing was then commenced, and was finally completed on November 2.

The portion of the District of Columbia over which this triangulation extends is north of Boundary street. Starting from the base Kengley's - U. S. Naval Observatory and Kengley's - Soldiers' Home, the southerly points in the scheme, the triangulation was carried thence westerly to beyond the District line and east through Tenallytown to the Reform School. The higher points in the survey are at Fort Reno near Tenallytown, and Swan at the junction of the Broad Run and Milk House roads, quite near the northern line of the District. The survey is indebted for the uniform courtesy manifested by the owners of property whose land was occupied by Mr. McCorkle in the execution of this work. The statistics are as follows:

| | |
|---|---|
| Number of stations occupied | 20 |
| Number of signals erected | 14 |
| Number of points determined | 61 |
| Number of observations | 3,944 |

At the close of the season Mr. McCorkle proceeded to Philadelphia and there completed the office-work of the triangulation. In January he returned to the office, and was engaged until June in making a careful examination of the original topographical sheets of the survey, in regard to the condition of which he has made a full and interesting report. He was subsequently employed in the triangulation of the Delaware River, which work is referred to under the head of Section II.

*Triangulation of the District of Columbia (southern portion).*—The reconnaissance for the scheme of principal triangulation of the District of Columbia was commenced in July by Subassistant C. H. Sinclair, starting on the bases Naval Observatory - Old Coast Survey Office and Naval Observatory - Insane Asylum. These being found impracticable, the line Naval Observatory - Hill was finally adopted. The month of July was employed in the reconnaissance and erection of signals. Observations were commenced at the Naval Observatory on July 31. Between July 31 and October 15 observations were completed at the stations, Naval Observatory, Kengley's, Stevens, Willard, Soldiers' Home, Hill, Dupont, Reform School, finishing the work of the principal triangulation. At Kengley's the instrument was mounted on the southeast chimney, forty feet from the ground. A brownstone slab, set in cement, was placed on the west end of the chimney, upon which cross-lines were cut to mark the station. At Soldiers' Home it was found necessary to build an interior tripod twenty-four feet in height, projecting through the trap-door at the top of the highest tower. The torsion caused by the necessarily limited spread of the tripod was counteracted, as far as possible, by the application of special braces, and by means of joists and braces the weight of the tripod was thrown, in a great measure, upon the stone wall at the base of the new roof. The same course was pursued at the Reform School, and observations at these two stations are found to compare favorably with those at the other points in the scheme. Some difficulty being encountered in observing the line Hill - Naval Observatory, a light was placed at the latter station, and that direction observed with a reference-mark at night, all of the other directions being referred to the same mark. Night observations were continued on three nights, from dark until eleven o'clock, but at no time was the light steady.

On October 16 Mr. Sinclair commenced the tertiary work to the southward and eastward. The reconnaissance having sufficiently advanced, the necessary observations were made from Reform School; the large theodolite was then dismounted and returned to the office. This work was discontinued on November 15, and from that date until December 2 Mr. Sinclair was engaged in measuring an angle of precision and preparing to connect the piers at Fort Myer (old Fort Whipple) with the Naval Observatory, for the purpose of special experiments relative to the velocity of light, conducted by Prof. Simon Newcomb, of that observatory. Field-work was closed on December 3, and resumed again in the following February. The work for Professor Newcomb, including the measurement of a base-line 374.62 meters in length on Analostan Island, the connection by triangulation of the axis of a revolving mirror at Fort Myer, with the pier supporting the reflectors near the Naval Observatory and with an arbitrary point on the base of Washington Monument, was finally completed by March 7. Subsequently Mr. Sinclair was attached to the telegraphic longitude party, under charge of Assistant Edwin Smith. The statistics of the triangulation are as follows:

| | |
|---|---|
| Number of stations occupied | 37 |
| Number of signals erected | 36 |
| Number of points determined | 66 |
| Number of angles measured | 435 |
| Number of observations | 6,634 |

*Topography of the District of Columbia.*—After closing work on the south coast of Long Island, as mentioned in a preceding abstract, Assistant J. W. Donn was directed to lay up the schooner Scoresby at Baltimore, and subsequently to proceed to Washington and commence a detailed topographical survey of the District of Columbia.

The triangulation for this work had already been executed by Assistant McCorkle and Subassistant Sinclair, but the office computation was not completed, and the points not immediately available. Accordingly, Assistant Donn was engaged until February, principally in running lines of level, measuring distances with the tape-line, and sketching in topographical details along the boundary of the city between Sixteenth Street extended and Lincoln Avenue. Much of this work was done while the snow covered the ground to a depth of six inches. Finding that a sufficient number of triangulation points had not been determined in certain portions of the District from which to extend the plane-table survey, several additional positions were determined, the stations

Soldiers' Home, French, and Wayland Institute being in turn occupied and observed upon. The line Soldiers' Home–Wayland was then made the base for the determination of the two additional points, New York Avenue and Keating's.

As soon as the projections were available, the topographical work was commenced in the area included between Boundary Street, Fourteenth Street extended, Mount Pleasant Avenue, and Seventh Street extended, by the request of the Engineer Commissioner of the District. This work was completed in February and the results furnished to the District Commissioners. Following this the work lying to the eastward of Seventh Street extended and across to Lincoln Avenue, covering the locality of the proposed lake and reservoir, was taken up.

On the 1st of April a second party was organized and placed in charge of Mr. W. C. Hodgkins, Aid, who had previously assisted in Mr. Donn's party. Toward the middle of May the two parties were placed in camp near Brightwood, near the principal part of the work which lies in the open country. It was found impracticable to run five-foot contours through wooded areas without extensive cutting. Before moving the parties, Mr. Hodgkins mapped the country north of Mount Pleasant Avenue from Fourteenth Street extended to and across Seventh Street extended. Subsequently he was principally employed in and about the Riggs road, Magnolia Avenue, and Rock Creek Church road.

The work of Assistant Donn, from the 15th of May until June 30, was directed to the extension of the survey along Lincoln Avenue, around the cemeteries and Soldiers' Home, and in the open country along the Bunker Hill, Bladensburg, Queen's Chapel, and Harewood roads. Lines of level were run along all the principal roads and the Baltimore and Ohio Railroad to the boundary of the District. Owing to the incomplete and at present disconnected condition of the work, it is impracticable to furnish statistics.

*Topography of site for new Naval Observatory in the District of Columbia.*—Towards the latter part of May, Mr. Charles Junken, of the Coast and Geodetic Survey Office, was directed to make a detailed topographical survey of the locality selected for the erection of the new Naval Observatory. This site is on the high ground between the Tenallytown road and Rock Creek, about one-half mile north of Road Street, Georgetown, D. C.

Mr. Junken took the field on June 1, and commenced work by determining the heights of a number of points near the proposed observatory site with reference to the mean high water of the Potomac River. For this purpose lines of levels were run from the city engineer's bench-mark, corner of High and Road Streets, Georgetown. The lowest point was found to be at the northeast corner of the site, which is 91.5 feet above mean high water, while the highest point is situated a short distance northwest of the mansion, being 280.7 feet above the same plane of reference. This portion of the work was finished by the 13th of June.

A base line 704.8 feet long was then measured with the chain, and upon this base was laid out a series of triangles with short sides, when situated in the forest, so as to obviate, as far as possible the necessity for cutting through the thick underbrush. Contour lines were then run to show lines, of equal elevation for every two feet of vertical height.

The field-sheet, on a scale of $\frac{1}{1200}$, being finally completed, the necessary connection with the triangulation of the Coast and Geodetic Survey was effected. The sheet inked by Mr. Junken, was turned in to the office at the close of the season, together with field-books of triangulation and levelings. A duplicate of the work was then furnished to the Superintendent of the Naval Observatory. Mr. F. C. Donn assisted in this survey. The statistics are as follows:

| | |
|---|---|
| Number of triangulation stations occupied | 4 |
| Number of angles observed | 12 |
| Number of stations occupied with plane table | 115 |
| Number of leveling stations established | 97 |

*Magnetic observatory at Washington.*—This observatory has been used as comparing or starting station for several parties during the latter half of the past fiscal year. The magnetic observers of the Polar Expeditions to Point Barrow, Alaska, and to Lady Franklin Bay, North Greenland, were instructed here by Mr. M. Baker. It was also used by Lieutenant Very, U. S. N., for testing his instruments and obtaining constants before he started on his magnetic trip to Canada. From want of an observer the usual declination and intensity observations in June had to be deferred this year; besides, the observatory was needed for the above-stated purposes, and the dip-circle belonging to it had to be given up to the Point Barrow party. This instrument, it is expected, will soon be replaced by a new one.

*Permanent trial base at Fort Myer.*—With a view of having a permanent test line for preliminary practice of parties taking the field for base measurement, as well as to secure an established line of known value for testing measuring bars at any time, a permanent "trial base" one kilometer in length has been laid down in the vicinity of Fort Myer, Va. The ends of this line are securely marked, and the marks are at a depth sufficient to be beyond the effect of climatic and hygrometric influences. As the frequent use of this line requires the ready means of transferring this underground mark to the surface, suggestions as to the best method of accomplishing the purpose were invited, and the plan suggested by Assistant O. H. Tittman was adopted. (See Appendix 13.)

*Pendulum observations.*—The pendulum experiments conducted during the year by Assistant Charles S. Peirce have, in great part, related to the effect upon the oscillation period of the walls of the receiver (or vessel within which the pendulum swings). It has hitherto been assumed that this effect is very small, and upon this assumption its value has been calculated by an approximate hydro-dynamical theory. Experiment has, however, unexpectedly shown that the effect, although naturally not large, is far from being very small. The mathematical theory is thus shown to be very imperfect, and it has become necessary to determine, experimentally, the effect above referred to. The alteration of the value of this effect involves alteration in other constants, and has important indirect results. Certain anomalous determinations of gravity are thus explained, and former experiments made by the Coast and Geodetic Survey are found to be even more accurate than had been supposed.

A new pattern of the reversible pendulum has been invented, having its surface as nearly as convenient in the form of an elongated ellipsoid. Three of these instruments have been constructed, two having a distance of one meter between the knife-edges and the third a distance of one yard. It is proposed to swing one of the meter pendulums at a temperature near 32° F. at the same time that the yard pendulum is swung at 60° F., in order to determine anew the relation between the yard and the meter. The other meter pendulum has been sent to Lady Franklin Bay, under the charge of Lieut. A. W. Greely, U. S. A., after having been oscillated at the Coast and Geodetic Survey Office by Mr. Israel, of Lieutenant Greeley's party. The oscillations were made under the personal direction of Assistant Peirce.

Observations to determine the force of gravity have been made at Washington and Baltimore. A new series of experiments has also been made to test the plan of oscillating pendulums on rollers. The result has been unequivocally unfavorable. Investigations upon the flexure of the pendulum support and upon the plan of swinging two pendulums upon the same stand have been continued. (See Appendix No. 14.) A memoir by Assistant Peirce upon the deduction of the ellipticity of the earth from pendulum experiments will be found in Appendix No. 15.

The measures of deviations of light by diffraction plates, forming a part of the work upon the spectrum meter alluded to in former reports, have been continued by Assistant Peirce, who has also made special experiments to determine the influence of the movement of the solar system upon the deviation. The results of these experiments and measures will be a matter of future publication.

*Hypsometry.*—The work assigned in July to Mr. H. F. Walling was the compilation of a map of that part of the Appalachian chain of mountains extending from the northern part of Maryland to the northern parts of Georgia and Alabama, many of the summits of the mountains between these limits having been occupied in the primary triangulation of the Coast and Geodetic Survey.

After obtaining all available data from this office and from outside sources, Mr. Walling took the field on October 1, in order to complete the collection of necessary information to make such triangulation as might be required to connect the existing maps and plans in his possession with the trigonometrical points of the survey, and to make barometrical and other observations over the region covered, for the purpose of representing its hypsometry.

The area over which work has been carried during the fiscal year comprises that portion of

Maryland lying between Parr's Ridge on the east and the North Mountain Range on the west, with some of the adjacent portions of Virginia and West Virginia. The location of nine points in the valley between Parr's Ridge and the Blue Ridge were determined with reference to the Coast and Geodetic Survey triangulation, and six more points between the Blue Ridge or South Mountain and the North Mountain were partially observed upon. Contours were drawn for each one hundred feet of difference of level. Over fifteen hundred miles of wagon roads were gone over with the aneroid barometer, and differences of level were noted between stream crossings, watersheds, etc. These have been approximately referred to the sea level by comparison with heights determined by the survey and with the profiles of railroad lines. Profiles of hills and ridges were made by measurements of horizontal and vertical angles, from mountains whose positions had previously been determined, and in many cases traverse surveys were made along the summits or ridge lines and in the ravines, accompanied by records of heights with aneroid barometers, one of which was stationery.

Upon the completion of the triangulation mentioned, the sheet containing the map of the territory described, comprising an area of more than sixteen hundred square miles already in an advanced state of progress, may be speedily completed.

*Telegraphic longitudes.*—After closing observations at Cape May, as noticed under Section II, for the determination of the latitude and longitude of that place, the party of Assistant G. W. Dean remained at Washington, D. C., the party of Assistant Smith being transferred to Strasburg, Va., where an observatory had been erected earlier in the season by Assistant Dean. Bad weather at Strasburg prevented the commencement of observations for longitude until June 14. Longitude observations between this place and Washington, D. C., were made on the nights of June 14, 15, and 16, when the observers changed stations, and similar determinations were made on the nights of June 18, 19, and 21.

Latitude observations were made at Strasburg by Subassistant C. H. Sinclair, with meridian telescope No. 13 on the nights of June 7, 8, 14, 15, 16, 18, 19, and 22, but the nights generally were cloudy and unfavorable.

Mr. Carlisle Terry, jr., was then directed to join the party at Strasburg, and, immediately afterwards, that party removed to Charleston, W. Va. On June 28 signals were exchanged between Washington, D. C., and Charleston, W. Va. This was the last work accomplished up to June 30.

The results of work during the season have been marked by greatly increased accuracy, due to improved instruments and methods. The transits have been fitted with new eye-pieces of high power, and have been reconstructed for latitude observations and fitted with new levels. New signal relays have been substituted for the polarized relays formerly used, and are found to give satisfactory results for transmission and armature time over both long and short circuits.

*Magnetic observations.*—The magnetic route followed by Subassistant Baylor, under instructions of June, 1880, was specially marked out with the design of furnishing magnetic information over a vast region, within which, previously, our knowledge of the distribution of terrestrial magnetism was exceedingly scanty, and to supply data for the future to serve for ascertaining the annual changes of the magnetic elements. The route passes chiefly through Northern Wisconsin, Minnesota, and Dakota, and takes in, on the way to and from those States, the special localities in regard to which magnetic information was most needed. The selection of magnetic stations through the States depends, at present, mainly upon the ordinary facilities for travel, since parties with special outfit and protection for independent action would be far too costly.

Subassistant Baylor took the field on July 5 and determined the azimuth and three magnetic elements at Clarksburg, W. Va. The stations subsequently occupied are specified under their proper section headings.

In the following June, Subassistant Baylor resumed field-work, and by June 30 had completed determinations of the three magnetic elements at Wheeling, Clarksburg, Parkersburg, Charlestown, and Alderson, W. Va., Covington and Wytheville, Va., and had partially completed observations at Marion, Va.

*Triangulation in West Virginia.*—The party of Assistant A. T. Mosman, organized in June, 1880, was employed during that month in the preliminary work of opening lines, posting heliotropers, and erecting signals. On July 1, camp was pitched at Briery Knob, Pocahontas County, West Virginia, a station more than forty-five hundred feet above the sea level. Observations were commenced at once and continued until July 24, when the party removed to Keeney Mountain, Summers County, West Virginia. Owing to the steepness of this mountain, the task of transporting the camp and instruments was a difficult one, but was finally completed by August 7. The geodetic instruments were mounted on the 11th, and on the 12th and 13th the astronomical observatory was built and the meridian telescope mounted for observations of time and latitude. The weather during August was unfavorable, only one day's observations for horizontal and vertical angles being obtained, but the nights were more favorable and observations for latitude were finished on September 5. From August 24 until September 22, observations of horizontal and vertical angles by day, and of time, latitude, and azimuth by night, were carried on simultaneously. Six miles of road were also cut through the wilderness from Job's Knob to Beech Knob, preparatory to the occupation of the latter. Observations at Beech Knob (over forty-one hundred feet in height) were obtained between October 8 and 21. Snow and very cold weather delayed the operations of moving camp from Beech Knob to Summersville, and during this interval Table Rock and Holmes' were cleared of trees, signals erected, and heliotropers posted at those stations. Work was commenced as Summersville on November 11, and continued until December 6, when work was closed, camp stored at Kanawha Falls, W. Va., and the instruments and records forwarded to the office.

Before the close of the season the weather became very unfavorable, fourteen heavy snows fell, and on one occasion the thermometer registered —18°. In spite of these and other retarding influences mentioned, Mr. Mosman succeeded in occupying four primary stations, two of which were high mountains, difficult of access, a result which is to be attributed to his energy and readiness to take advantage of every favorable opportunity for observing. Mr. W. B. Fairfield rendered effective service in the party as recorder. Field statistics:

| | |
|---|---|
| Stations occupied | 4 |
| Observations of horizontal angles | 1, 152 |
| Observations of latitude | 103 |
| Observations of time | 260 |
| Observations of azimuth | 222 |
| Observations for measurement of zenith distance | 858 |
| Observations for differences of heights | 542 |

Assistant Mosman resumed field-work in West Virginia on May 20 at Ivy Mountain, a steep summit, having an elevation of about one thousand seven hundred feet, inaccessible to wagons, rendering necessary the transportation of the tents and instruments on the backs of men for a distance of three miles. Observations were commenced on June 13 and continued with favorable weather until the 26th, when camp was moved to Table Rock. The statistics to July 1 are as follows:

| | |
|---|---|
| Observations of horizontal angles | 416 |
| Directions on tertiary objects | 38 |
| Stations occupied | 1 |
| Stations observed upon | 7 |
| Observations for differences of heights | 83 |
| Observations for zenith distances | 96 |

Mr. W. B. Fairfield was attached to the party as extra observer.

From the Computing Division, Assistant C. A. Schott reports that the Blue Ridge triangulation closed remarkably well at the junction-line in North Carolina, both in length and azimuth.

## SECTION V.

### SOUTH CAROLINA AND GEORGIA, INCLUDING COASTS AND SEAPORTS, BAYS AND RIVERS.

*Tidal Observations.*—At the request of General Q. A. Gillmore, a good self-registering tide-gauge was put in order and sent early in July, 1881, to Lieut. B. D. Greene, United States Engineers, at Charleston, S. C., who is to have charge of it. It was loaned for the purpose of securing a continuous series of tidal observations at Fort Sumter. The old stations at the city were in some respects objectionable, and it will probably be easy to secure a series of observations, at or near the fort, which will be better for engineering and other purposes than any that have yet been made in that quarter.

## SECTION VI.

### FLORIDA PENINSULA, INCLUDING REEFS, KEYS, SEAPORTS, RIVERS, AND ADJACENT PORTIONS OF THE GULF STREAM.

*Deep-sea soundings, dredgings, and temperature observations.*—During the month of June, 1880, the steamer Blake, under command of Commander J. R. Bartlett, U. S. N., Assistant Coast and Geodetic Survey, was thoroughly repaired at Providence, R. I., for the continuation of the deep-sea work of sounding, dredging, and temperature observations. The latter part of June was spent in experimenting with a cylinder devised by Lieut. Commander C. D. Sigsbee, U. S. N., for obtaining specimens of ocean life at intermediate depths, Lieutenant-Commander Sigsbee and Prof. A. Agassiz being on board.

On June 27 the Blake left Providence for a position off the George's Bank, due east from Nantucket. Prof. A. Agassiz joined the vessel on the following day to take charge of the specimens obtained.

Off George's Bank soundings and hauls of the trawl, with observations of surface and bottom temperatures were obtained in depths of from seventy-two to one thousand two hundred and forty-two fathoms with excellent results, many of the hauls being exceptionally rich in animal life. All of these hauls were made with the trawl, and the apparatus worked well. The weather generally was very favorable.

From the position off George's Bank the vessel moved to a location south of Newport, where hauls were made with good results at depths ranging from two hundred and sixty to four hundred and sixty-six fathoms. Lieutenant-Commander Sigsbee's cylinder was used to advantage in obtaining specimens of life at intermediate depths.

On July 7, after a short detention at Newport, caused by bad weather, the vessel sailed for Charleston, S. C. To the southeastward of Cape Romain a sounding and haul of the dredge was obtained in one hundred and forty-two fathoms. Thence the vessel steamed to the eastward, taking frequent soundings in order to find the depths at which Professor Agassiz wished to dredge. The depths on this line were unexpectedly small, the axis of the Gulf Stream being crossed before a depth of three hundred fathoms was found at any sounding. The bottom is composed of hard coral, upon which but few traces of animal life were discovered, although along its edge successful hauls were made with the trawl. For fifteen miles or more from the one hundred-fathom line a strong current was experienced running to the southwest, dragging the vessel in that direction, when the trawl was down, at the rate of two knots an hour. Towards the axis of the stream the current took a northeasterly course, running at the rate of 2.6 knots an hour. The water deepened to three hundred and eighty-two fathoms east of the axis, but shoaled again to three hundred and thirty-seven fathoms.

As the cruise was primarily for dredging purposes, these soundings were not continued; but the Stream was followed along its axis to the northward, soundings being taken every five miles, with depths of from two hundred and thirty-three to one thousand three hundred and eighty-six fathoms, from latitude 32° to latitude 33° 30′ north. After reaching a depth of one thousand three hundred and eighty-six fathoms the vessel ran towards Cape Lookout, sounding as far as the hundred-fathom line, and taking a number of hauls with the trawl with excellent results. On the way to Hatteras hauls were made in one thousand six hundred and thirty-two, one thousand five hundred and ten, six hundred and three, and one hundred and fifty-seven fathoms. The bottom off Hatteras was found to slope too abruptly to admit of any dredging, but very good hauls were made forty miles north of the Cape in one thousand and forty-seven, eight hundred and seventy-six, six hundred and twenty-three, and sixty-five fathoms. The next line dredged was off the Delaware, where hauls were made in depths ranging from eighty-nine to one thousand one hundred and eighty-six fathoms. These hauls were exceedingly rich in results. The line to the southward of Newport was completed by making hauls at twelve localities, in depths of from one thousand three hundred and ninety-six to twenty-four fathoms. This closing the work as laid out in the instructions for the cruise, the vessel returned to Newport, arriving there on July 20.

Lieut. C. F. Wandell, of the Royal Danish Navy, accompanied the party on board the steamer Blake, and manifested great interest as well as intelligence in regard to the details and appliances for deep-sea soundings. After the return of the vessel to Providence he expressed in a communication addressed to the Superintendent his cordial thanks for the attention shown by Commander Bartlett and his fellow-officers in furthering the objects of his trip.

During the fall and winter the Blake was laid up at Providence, R. I., and no active work was done by the party, with the exception of two small local hydrographic surveys for special purposes. In the following spring the vessel was refitted for sea, and received on board a new electrical apparatus, devised by Siemens, of London, for recording deep-sea temperatures. These preparations being finally complete, the Blake left Providence on May 4 for a cruise in the Gulf Stream.

The general limits of the work executed during May and June are between Jupiter Inlet, Florida, and Currituck Light-House, North Carolina, between which points lines of soundings normal to the coast were run, extending across the Bahama Banks and, after leaving those banks, including the whole area swept by the Gulf Stream. These lines were run out from the coast for a distance of from sixty to three hundred miles, and about sixty miles apart. Along these lines soundings and serial temperatures with specimens of bottom were taken at distances of from five to ten miles, according to the locality. No dredging-work proper was attempted.

By the end of June, at which date this report closes, two hundred and eight sounding stations had been occupied, and temperatures recorded at seventeen stations on nine lines normal to the coast. The depths on these lines range from seven and one-half fathoms near shore to two thousand one hundred and thirty-four fathoms at the extremity of one of the most southerly lines, and were found to agree well with those taken near the same localities during the preceding season. The strong current previously noticed, setting to the southwest for fifteen miles or more from the hundred-fathom line off Charleston, was again experienced. On the line out from Savannah and on the return line from Charleston, when on the west side of the Gulf Stream, a strong "rip" about a mile in width was encountered. During the previous summer the Blake had crossed this "rip,' and from the reports of pilots and others its existence was found to be well known.

The Blake was still engaged in deep-sea work at the close of the fiscal year.

The following officers were attached to the vessel during the year, and rendered valuable assistance in the deep-sea work and management of the vessel: Lieut. Charles C. Cornwell, U. S. N., Masters G. W. Mentz and Henry Morrell, U. S. N., Ensigns Lucian Flynne and E. L. Reynolds, U. S. N.

*Triangulation, topography, and hydrography of Indian River, Florida.*—To continue the survey of Indian River on the east coast of Florida, Subassistant W. I. Vinal started for the field on October 20. Preliminary arrangements, retarded by heavy rains, were not completed until November 16, when the actual field work commenced. The triangulation was extended southward from stations occupied during the previous season, to furnish points for the extension of the topography and hydrography.

At the outset it was found that many of the signals erected during the preceding season had been blown down by the hurricane of August 28 and 29, 1880, and in some cases the river had risen to such a height as to displace the station marks. It was therefore necessary to re-erect and in some cases to re-determine the signals at several points. This being accomplished, the regular work was taken up and steadily prosecuted until the close of the season. The weather during the progress of the work was for considerable periods unfavorable, high winds prevailing during five months. But little rain fell and the river was consequently low. Extensive tracts were burnt over by settlers clearing land, filling the atmosphere with smoke and preventing observations. Much cutting was rendered necessary by the heavy undergrowth, and scaffold signals of considerable height were found necessary to secure intervisibility. As in former seasons, however, driftwood was used exclusively for building signals, and this was found to save much delay. The western shore of the river south of "Parks" triangulation point is a long, narrow strip of sand separating the river from extensive marshes, but notwithstanding this the western limit of the topographical sheet includes the wood line or edge of the pine barren. Consequently, as the work advanced southward the ten-foot curve of elevation fell outside of the usual limits. In spite of these difficulties satisfactory progress was made, as will be shown by the following statistics:

| | |
|---|---|
| Number of signals re-erected | 15 |
| Number of signals redetermined | 4 |
| Number of new signals erected and determined for hydrography | 9 |

Triangulation:

| | |
|---|---|
| Number of signals erected | 39 |
| Number of scaffolds erected | 13 |
| Number of stations occupied | 14 |
| Number of positions determined | 47 |
| Number of horizontal angles measured | 192 |
| Number of observations with theodolite | 3,192 |
| Extent of triangulation, statute miles | 18¾ |
| Area of triangulation, square miles | 38 |

The topographical features are marshy islands, low pine lands, swamp, mangrove, palmetto, scrub and live oak. The land varies in height from thirty feet, near the mouth of Sebastian Creek, to a few inches above the surface of the river. Large areas are overflowed at high water.

Statistics of topography:

| | |
|---|---|
| Shore line (river), miles | 109½ |
| Shore line (ocean beach), miles | 15 |
| Shore line (ponds), miles | 13½ |
| Shore line (creeks), miles | 14½ |
| Area of topography, square miles | 27 |

Statistics of hydrography:

| | |
|---|---|
| Number of miles of sounding lines | 290 |
| Number of angles observed and plotted | 1,610 |
| Number of soundings recorded | 22,837 |

Information required by the outside party in the steamer Bache, Lieut. E. B. Thomas commanding, was furnished, including a projection showing all new points on the ocean beach and descriptions of stations.

Mr. E. L. Taney, Aid, was attached to the party, and performed good service in the topography.

At the close of the season the Steadfast was laid up in Turkey Creek, and every precaution taken for her safety.

*Hydrography of Cape Canaveral Shoals and south of Cape Canaveral.*—Having closed work in the vicinity of Egmont Key and off Light-House Point on the west coast, Lieut. E. B. Thomas transferred his party to the vicinity of Cape Canaveral, arriving there on April 18, and at once commenced a survey of Canaveral Shoals, upon a projection furnished by the office. The work was steadily prosecuted, with exceptionally favorable weather, and by May 19 the projection covering Canaveral Shoals and two additional ones to the southward of Cape Canaveral were furnished. The vessel then sailed for New York, arriving there on May 23. In addition to the regular work of sounding, a number of bottom specimens were obtained, and were turned in to the office by Lieutenant Thomas with the sounding books and other records of the season's work.

The rapid and successful execution of this work is greatly due to the efficient assistance rendered by the officers attached to the vessel. These were Lieut. J. A. H. Nickels, U. S. N., Masters Charles J. Badger, U. S. N., Frank A. Wilner, U. S. N., and Henry F. Reich, U. S. N.

In the execution of hydrography south of Cape Canaveral, triangulation points and descriptions of stations were furnished by Subassistant W. I. Vinal, who was there engaged in a survey of the lower portion of Indian River.

The statistics of the season's work as given by Lieutenant Thomas for both Sections VI and VII include in the aggregate—

| | |
|---|---|
| Number of soundings recorded | 22,697 |
| Number of angles measured | 3,521 |
| Number of miles of soundings | 1,193½ |

## SECTION VII.

### WESTERN FLORIDA, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS.

*Hydrography off Egmont Key and off Light-House Point.*—Lieut. E. B. Thomas, U. S. N., Assistant in the Coast and Geodetic Survey, was assigned in December to work on the west and east coasts of Florida. At the conclusion of work on the coast of Maine the steamer Bache had been laid up at Baltimore for repairs. These being finally completed, and other necessary preliminary arrangements made, the hydrographic party sailed from Baltimore on December 22, reaching Norfolk on the 27th. There the vessel was delayed until January 15, taking additional supplies. Tampa Bay was reached on February 3, and work was immediately commenced upon a projection off and to the northward of Egmont Key Light. On its completion another projection south of Egmont Key Light was taken up and finished, after which the vessel was transferred to work on a third sheet off Light-House Point. This work was completed on April 3, and the vessel then sailed for Key West. The party was subsequently engaged upon hydrography on the east coast of Florida, noticed in a preceding abstract. That abstract contains also a summary of the statistics for the season's operations. Progress was somewhat retarded by the unusual severity of the weather.

The officers attached to the vessel were Lieut. J. A. H. Nickels, U. S. N., and Masters Charles J. Badger, Frank A. Wilner, and Henry F. Reich, U. S. N., all of whom manifested an active interest in the advancement of the work.

## SECTION VIII.

### ALABAMA, MISSISSIPPI, LOUISIANA, AND ARKANSAS, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS.

*Mississippi River survey.*—As mentioned in the last annual report, the survey of the Mississippi River in connection with the work of the Mississippi River Commission had, at the close of the fiscal year 1880, made good progress. At that date the triangulation of the river was completed between the Gulf and Helena, Ark., with the exception of portions between Bayou Sara and Baton Rouge, La., between Providence, La., and Greenville, Miss., and between Vicksburg, Miss., and Providence, La. The topography had also been advanced in several localities.

During the fiscal year ending June 30, 1881, the gaps in the triangulation were closed, with the exception of that portion between Greenville, Miss., and Helena, Ark., the completion of which work will give a connected system of triangulation between the Gulf and Memphis, Tenn.; an azimuth was measured at the base line near Greenville, Miss., and that base connected with the triangulation; the hydrography was extended from a point four miles below Donaldsonville, La., to Plaquemine, La., and the lines of geodetic leveling were completed between Carrollton, La., and Greenville, Miss. The great accuracy attained in the last-mentioned work is worthy of remark. In a distance of four hundred and fifty miles the results of two distinct lines accord within a limit of error of little more than one inch. Basing conclusions on these results it is probable that the average limit of error of a determination by the same methods of the relative levels of the Atlantic and Pacific Oceans will fall within two and one-half inches.

The following *résumé* of the leveling operations on the Mississippi River is furnished by Mr. C. A. Schott, Assistant in charge of the Computing Division.

The whole operation was divided and executed in four parts, viz:

Part 1. From Greenville, Miss., to Milliken's Bend, La., Assistant Tittmann and Mr. Weir, January to May, 1880.

Part 2. From Milliken's Bend, La., to opposite Rodney, Miss., Mr. Weir, November, 1880, to January, 1881.

Part 3. From opposite Rodney, Miss., to Pointe Coupée, La., Subassistant Braid, November, 1880, to January, 1881; and—

Part 4. From Pointe Coupée to Carrollton, La., Subassistant Braid, December, 1879, to May, 1880.

A double line was run throughout, and in many places additional check lines; the direction of measure was occasionally changed, generally for alternate sections.

The mean error in a determination of height as developed in one kilometer, the probable error in one kilometer, the length of line gone over and the resulting probable error in the assigned height for each part, with consideration that the line was double (and frequently more than double), are given in the following table:

| Part. | In one kilometer. | | (Single) length of route in kilometers. | Probable error in resulting difference of height. | Remarks. |
|---|---|---|---|---|---|
| | Mean error. | Probable error. | | | |
| | *Mm.* | *Mm.* | | *Mm.* | |
| 1 | ±2. 40 | ±1. 62 | 166. 9 | ±14. 8 | Whole development of line between Greenville and Carrollton 731.8 kilometers, or 454.7 statute miles nearly.<br>Probable uncertainty in the result, ±26.6mm or ±1.05 inch nearly. A degree of accuracy which may be regarded as quite sufficient for the object in view. |
| 2 | 1. 88 | 1. 27 | 103. 1 | 9. 1 | |
| 3 | 1. 99 | 1. 34 | 162. 8 | 12. 1 | |
| 4 | 1. 95 | 1. 32 | 299. 0 | 16. 1 | |
| Average value | ±2. 06 | ±1. 39 | .......... | .......... | |
| Sum total | | | 731. 8 | ±26. 6 | |

The following table gives for each part the number of the instrument used, the number and position of the initial and terminal bench-marks, the resulting difference of heights from the first and second measure, and the final mean, together with the total difference of heights:

| Part. | Number of instrument. | From B. M.— | To B. M.— | First line. | Second line. | Mean. |
|---|---|---|---|---|---|---|
| | | | | *M.* | | *M.* |
| 1 | 3 and 36 | 1 at Greenville | 188 at Milliken's Bend | 9. 8373 | 9. 7970 | 9. 8172 |
| 2 | 3 | 188 at Milliken's Bend | 297 or LXXIII opposite to Rodney. | 8. 4269 | 8. 4291 | 8. 4280 |
| 3 | 1 | LXXIII opposite Rodney | 127 Red River Landing | 5. 7615 | 5. 7665 | 5. 7655 |
| 4 | 1 | 127 Red River Landing | 1 at Carrollton | 13. 0435 | 13. 0590 | 13. 0512 |
| Sum total | | | | | | 37. 0619<br>±. 0266 |

By which amount the Carrollton B. M. lies below the Greenville B. M.; $37^{m}.0619$ is equivalent to 121.595 feet.

There is also a *branch* line of levels crossing the Mississippi River from B. M. 127, near Red River Landing, to Fort Adams B. M. XLIX, the latter mark being $4^{m}.9487$ above the former.

Although our levels do not connect (and were not intended to be connected by us) with the water surface of the Mississippi River, they, nevertheless, indicate roughly that between Greenville and Carrollton the average fall of the river will probably not differ much from five centimeters per kilometer or from three and one-quarter inches per statute mile.

We have also the following statistical matter:

| | Date of execution. | Total length. | No. of bench-marks. |
|---|---|---|---|
| Spirit levelings between— | | Km. | |
| Greenville, Miss., and Milliken's Bend, La | January to May, 1880 | 175. 0 | 188 |
| Milliken's Bend and opposite Rodney, Miss | November, 1880, to January, 1881 | 104. 7 | 109 |
| Opposite Rodney and Pointe Coupée, La | November, 1880, to January, 1881 | 166. 4 | 88 |
| Pointe Coupée and Carrollton, La | December, 1879, to May, 1880 | 325. 7 | 202 |
| Total | | 771. 8 | 587 |

The connection of the above line of levels with the mean Gulf level remains to be made.

*Tidal observations.*—A self-registering gauge was made by Fauth & Co., of Washington, under the supervision of the Chief of the Tidal Division and after his plans, and sent to General B. M. Harrod, State Engineer of Louisiana and member of the Mississippi River Commission, by whose order it was made and for whom it is being used at Lake Borgne, Louisiana, where an extended series is contemplated to give a reference plane for the survey of the river.

*Hydrography.*—The hydrography of the Mississippi River, executed by Lieut. Uriel Sebree, U. S. N., Assistant in the Coast and Geodetic Survey, with the steamer Gedney, extends from a point four miles below Donaldsonville, La., to within two miles of Plaquemine. Work was commenced in December on a projection, scale $\frac{1}{5000}$, extending from the point just mentioned, four miles below Donaldsonville to Donaldsonville. At a wharf at this place a tide-gauge was established and connected by a line of levels with the bench-mark No. XVII of Assistant Andrew Braid, which is on the left bank of the river, one mile above Donaldsonville. To this the soundings will be referred. From information received at the locality, Lieutenant Sebree reports that the zero of this wharf-gauge is probably at about the low-water mark of the river for that year. But this is uncertain.

The general plan pursued in the execution of this work was to run sections normal to the river at a distance of a half mile apart. At each section four lines were run, two running in one direction and two in the other. The lines in the sections are fifty meters apart. On these lines, which were run in the large steam launch No. 3, it was found necessary to fix the position of the soundings by frequent angles from the shore. Where the current was comparatively constant and the depth not too great, angles were taken only at every second or third sounding. The time for each angular observation was indicated by the dropping of a ball on the launch. In deep water it was found necessary to stop the boat at each sounding. A lead weighing from ten to twelve pounds was used, with a small line, and the latter frequently compared each day so as to detect any change of length. On each range, the distance from the water's edge to the top of the level was chained. Some of the lines of soundings were run twice, and additional soundings were made where needed, the positions being plotted by angles taken from the boat.

Work was closed on the 11th of April, having then extended to within two miles of Plaquemine. The vessel was then transferred to work on the coast of Texas, which will be noticed under the head of Section IX. The officers attached to the Gedney were Lieut. E. M. Hughes, U. S. N.; Master J. W. Stewart, U. S. N.; and Ensigns M. L. Wood and W. B. Caperton, U. S. N. All manifested much energy and an intelligent interest in the prosecution of the work.

*Triangulation.*—In October Mr. C. H. Van Orden, Aid, was assigned to the charge of a triangulation party on the Mississippi River. He arrived at New Orleans on October 23, fitted the schooner Research for the work, and arrived at Bayou Sara, La., on November 1. Here the triangulation was commenced, connecting with the stations Depot, S. E. base, and Alexander Creek, occupied by Assistant Dennis during the preceding season. As the work was extended southward much heavy cutting was found necessary, and reconnaissance was difficult. Severe storms and unusual cold prevailed during the winter and retarded progress. An eight-inch micrometer microscope direction instrument made by Fauth & Co., was used in this work, and was found well suited for the class of observations required. Five positions were generally taken, and the observations when possible were made at one setting of the instrument.

On the bluffs at Port Hudson the station Slaughter was securely marked and referred to a stone monument carried back from the bank in order to secure a permanent mark on the bluffs. Where practicable the stations of Assistant Granger's work were included in the scheme.

Mr. Van Orden's field computation of the length of the Baton Rouge base from Bayou Sara base, as determined by triangulation, agrees with the measurement of Assistant Ogden within $.055^{m}$, a satisfactory result considering the nature of the scheme. The statistics are appended:

| | |
|---|---|
| Number of stations occupied | 63 |
| Number of points determined | 75 |
| Number of miles of river triangulated | 35 |

At the close of the season the schooner Research was laid up at New Orleans, and Mr. Van Orden proceeded to Washington, reporting in person at this office.

*Triangulation.*—Assistant Dennis organized a party at Natchez during the latter part of October, and left that place with the steamer Barataria for Lake Providencu, La., on the 1st of Novemder. Starting from the Lake Providence base, the triangulation was extended up the river by a series of quadrilaterals to Walnut Point, where a connection was made with the work of Assistant Charles Hosmer, extending down from Greenville, Miss. The weather during the season was unfavorable for field-work, and from January to the close of the season the water in the river was so high as to cause inconvenience. Mr. J. B. Boutelle served acceptably in the party as recorder. The statistics are as follows:

| | |
|---|---|
| Number of signals erected | 57 |
| Number of stations occupied | 59 |
| Number of angles measured | 11,221 |
| Number of points determined | 38 |
| Number of miles of river triangulated | 47 |
| Number of miles of cutting | 32 |

At the close of the season the steamer Barataria was laid up at Natchez in charge of a ship-keeper, and Mr. Dennis reported at Washington preparatory to taking up topographical work on the coast of Maine.

*Geodetic leveling.*—The leveling work executed by Assistant Andrew Braid between Pointe Coupée and four miles below Saint Joseph's, La., was fully discussed in his report of April 5, 1881, which was given in the Appendix of the Annual Report for 1880. The report of the Chief of the Computing Division, stating the results of the final office computation of this work, bears witness to the care and precision of the observer, as well as the excellence of the methods employed.

*Triangulation.*—Assistant Charles Hosmer joined the steamer Hitchcock at Baton Rouge, La., on October 20, and after organizing his party proceeded to Vicksburg, Miss., and commenced the triangulation in that vicinity. On November 15 the work of the former season was connected with the triangulation from the Delta base. This connection was not completed during the previous season owing to the high stage of the river. Work was then taken up at Henderson and continued to a connection with the base at Lake Providence, La. During the prosecution of this triangulation operations were facilitated by the low water in the river, but the weather was generally unfavorable.

On the 14th of February, Assistant Hosmer was transferred to the work commenced by Assistant Boyd in the vicinity of Greenville, Miss., and carried it down to Walnut Point, where a connection was made with the work of Assistant Dennis on the 5th of March. The vessel then returned to Greenville, took on board a portion of the materials and outfit saved from the wrecked steamer Baton Rouge, and thence proceeded to Baton Rouge, La., where the party was discharged and the Hitchcock securely laid up. Thence Assistant Hosmer proceeded to Washington, D. C., and reported in person at the office. Subassistant Joseph Hergesheimer was attached to the party and rendered efficient service in the triangulation.

The original and duplicate records of the work were turned in to the office at the close of the season. The field statistics are given below:

| | |
|---|---|
| Number of signals erected | 47 |
| Number of stations occupied | 55 |
| Number of angles measured | 287 |
| Number of points determined | 68 |

*Triangulation.*—To continue the Mississippi triangulation, Assistant C. H. Boyd organized a party at New Orleans, and arrived at the working ground with the steamer Baton Rouge on November 3. The first work necessary preliminary to taking up the regular triangulation of the river was the selection of a base-site and measurement of a base-line near Greenville, Miss. After the site was selected and cleared heavy rains retarded the measurement. During these unfavorable intervals the triangulation was laid out and executed, connecting the base with the astronomical station made by Assistant Edwin Smith in 1878, and thence extended some eight miles down the river.

On the 24th of December the vessel was moved to Old Greenville landing, where a small observatory and brick pier were built over the south base for azimuth observations.

On the night of the 26th a strong northerly wind pressed the vessel upon the bank, dragging the anchor and holding her bow against the shore in spite of all efforts to get her off. In the meanwhile the river was falling rapidly, and the position of the vessel became more critical from day to day. Efforts to get her off proved ineffectual, and finally she sank stern foremost. The records and instruments, however, were saved. On the 13th of January, the United States snag-boat John C. Meigs was sent to the assistance of the Baton Rouge, and was employed until the end of the month in endeavoring to raise the vessel. On three occasions she was raised to the surface, but the chains parted, and she again sank as before. These efforts were finally abandoned only when the river had risen so as to entirely cover the Baton Rouge, the water being some twenty feet above that of December.

Seeing that there was no reasonable prospect of saving the vessel, Mr. Boyd was directed to dispose of the wreck and store the rescued property at Greenville. He reported at this office on February 20.

Mr. Carlile Terry, jr., and Mr. George F. Bird, Aids, were attached to the party, and rendered valuable assistance in field-work and in the attempts to save the vessel. The statistics of the work executed are as follows:

| | |
|---|---|
| Number of signals erected | 11 |
| Number of stations occupied | 8 |
| Number of angles measured | 39 |
| Number of directions observed | 81 |
| Number of geographical positions determined | 9 |

The base-line was measured twice, and a plane-table survey of the base-line made. The levels of the base were also connected with the precise levels of the Mississippi River. An observatory and pier were built over the south base for azimuth, the determination of which was subsequently made by Assistant Edwin Smith.

## SECTION IX.

### TEXAS, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS.

*Topography.*—To continue the topography of the Laguna Madre, coast of Texas, Assistant R. E. Halter took the field on October 15 and immediately proceeded to organize a party. The camp equipage had been previously moved from the lower part of Padre Island to within a short distance of Murdock Landing on the same island. Here a violent hurricane had been experienced, but without material damage to the camp outfit. Many of the signals were, however, blown down, and these it was necessary to re-erect before resuming the survey. The topography was commenced October 20, and was continued steadily until the close of the season. The weather during the winter was unfavorable, extreme cold prevailing with snow-falls unprecedented in that locality. Despite the adverse conditions by the end of June all of the work was finished that could be expeditiously done from the position occupied. During the month of June an azimuth was measured at Venado Station. The statistics of the work are given below:

| | |
|---|---|
| Shore line surveyed, miles | 380 |
| Number of observations for time (with sextant) | 292 |

Azimuth observations:

| | |
|---|---|
| Number of observations on star direct and reflected | 128 |
| Number of observations on mark | 64 |
| Number of observations to connect mark with triangulation | 84 |

*Hydrography near Padre Island, coast of Texas.*—As mentioned in a preceding abstract, Lieut. Uriel Sebree was engaged in the hydrography of the Mississippi River until April 11. He then proceeded with the steamer Gedney to New Orleans, where the vessel was docked for some necessary repairs. The Gedney arrived at Galveston towards the latter part of May, having stopped on the way down to re-erect signals on Padre Island.

Work was commenced at the north end of Padre Island on May 18, and continued when practicable until its completion on June 12, when the vessel sailed for Pensacola.

The triangulation signals erected by Assistant R. E. Halter were found without difficulty, and were easily made available for the hydrographic work. The work began at a point eight miles south of Corpus Christi Inlet at the close of the hydrography of the preceding season.

The general plan of operations adopted was as follows: A line of soundings was run from the beach out to a point fifteen miles distant from the beach and six miles below the starting point, then returning to the beach at a point twelve miles below the place of departure; thence a line was run up the coast close to the beach for six miles, and the original operations were repeated. This system gave crosses for the lines of soundings about seven and a half miles out from the beach in from eleven to fourteen fathoms, and a line parallel to the beach in from two and a half to three and a half fathoms. In addition a line was run parallel to the beach, and three or four miles from the shore, in from eight to ten fathoms. Short lines were also run in boats from the beach out to the three-fathom curve, abreast of nearly all the signals, or about every six or seven miles.

Great care was observed in sounding, and in doubtful cases the vessel was stopped and the sounding repeated.

In the course of this work Lieutenant Sebree developed by soundings a locality of broken ground from twenty to twenty-five miles north of Brazos Light-House, and having from eight to eleven fathoms of water over it. This locality will be known on the charts as "Sebree Ground."

To the eastward of this broken ground, twelve miles from the beach and twenty-two and a half miles north, 16° east of Brazos Light-House, a spot was found having from fifteen and a half to sixteen fathoms upon it, with eighteen fathoms all around it. The ground was hard, and the specimen cup brought up a piece of coral. A line of soundings was obtained all around this spot in from seventeen to nineteen fathoms. Only one cast of fifteen and a half fathoms was obtained.

Several short lines were run off Brazos Harbor and several lines in the harbor. One line was run over the bar of that harbor. A line was also run out from the mouth of the Rio Grande, normal to the coast for fifteen miles.

A number of specimens of the bottom were obtained, some general observations of the currents were made, and tides were recorded at a temporary gauge on the light-house wharf, Brazos Harbor.

Lieut. E. M. Hughes, U. S. N., Master J. W. Stewart, U. S. N., and Ensigns M. L. Wood and W. B. Caperton, U. S. N., were attached to the vessel, and rendered efficient assistance during the execution of this work. The statistics are appended:

| | |
|---|---|
| Number of signals erected | 3 |
| Number of signals re-erected | 11 |
| Number of signals determined | 7 |
| Number of angles measured | 1,027 |
| Number of soundings recorded | 5,332 |
| Number of miles of sounding lines | 697.9 |

## SECTION X.

### CALIFORNIA, INCLUDING COAST AND SEAPORTS, BAYS AND RIVERS.

*Magnetic observations.*—In September, 1880, Lieut.-Commander H. E. Nichols, U. S. N., Assistant Coast and Geodetic Survey, received instructions for a magnetic cruise along the coasts of Lower California, Mexico, and Central America, including some of the outlying islands. The steamer Hassler had previously been thoroughly repaired and refitted at San Francisco for this work, and on the receipt of the necessary instruments from the office, arrangements were at once made to commence the season's operations.

Observations were first made at the station Presidio at San Francisco. As soon as these were completed, the Hassler went to sea, steaming first to Guadalupe Island for observations at that place. Here, owing to rough weather, a landing was impracticable, and the vessel accordingly proceeded to Clarion Island and Socorro Island, where observations were successfully obtained. At the latter island work was interrupted by a gale placing the vessel in an unsafe position on a lee-shore, to avoid which it was deemed advisable to slip the cable and go to sea. On the vessel's return observations were completed, but the anchor left behind was found to be broken and useless.

From Socorro Island the Hassler steamed to La Union in San Salvador, where observations were taken for declination, dip, and intensity. Here the regular work of the season began. After the occupation of this station observations were made and recorded at the following points, following the coast line to the northward: Acajutla, Champerico, Salina Cruz, Port Escondido, Acapulco, Isla Grande, Manzanillo, San Blas, Point Ignatio, Santa Barbara Bay, Guayamas, Tiburon Island, Rocky Point, Philipp's Point, Point San Felipe, San Luis Gonzalez Bay, Santa Teresa Bay, Santa Maria Cove, Mulege, Loreto, Isle San Josef, Pichilinque Bay, La Paz, Mazatlan, San Jose del Cabo, Cape San Lucas, Magdalena Bay, Pequeña Bay, Point Abreojos, Ascension Island, Cerroo Island, Guadalupe Island, San Geronimo Island, San Martin Island, Todos Santos, San Diego, San Pedro, Santa Barbara, San Luis Obispo, Monterey, and Presidio. Observations for declination, dip, and intensity were made at all of the stations named with two or three exceptions, each station occupied was securely marked for future reference, and full descriptions of each are given in the records turned in by Lieutenant-Commander Nichols.

At Guadalupe Island, which was at that time imperfectly represented on the charts, a reconnaissance was made sufficient to give its general outlines and topography for such representation. A survey of this island, it was ascertained, had also been ordered by the Mexican Government, and the vessel carrying the party for that work was seen by the Hassler on her return from Guadalupe.

The astronomical positions at the points occupied were approximately determined from the vessel by single meridian altitudes and single time sights; the time was kept by three chronometers, a fourth being used for making the shore observations.

Lieutenant-Commander Nichols reports that the navigation of the entire coast visited was found very easy, and a pilot was not required.

The Hassler arrived at San Francisco after the completion of this work early in April. The following officers were attached to the Hassler during this cruise, and rendered efficient service: Lieut. W. T. Swinburne, U. S. N.; Master Charles T. Putnam, U. S. N.; Ensigns Frederick W. Coffin, Waldemar D. Rose, and Charles F. Pond, U. S. N.

*Tidal observations.*—A series of tidal and meteorological observations, to be comparable with similar ones made on the western coast of the United States, has been in progress at Mazatlan, Mexico, since July, 1879, conducted by Mr. Fiacro Ouijano, a civil engineer at that place. A self-registering gauge has been used, and the tabulated results, obtained by him and his aids, have been sent monthly to the Coast Survey Office, and he has been kept supplied with record paper for the curves and blank tabulation forms for keeping up the work.

*Hydrography.*—To close the gap in the hydrography of the California coast between Point Arguello and Point Sal, Lieut. E. H. C. Leutze, U. S. N., Assistant Coast and Geodetic Survey, proceeded to that locality with the steamer McArthur in August, 1880, and, the preliminary operations being completed, soundings were commenced on the 7th of that month, and steadily prosecuted until October 6, 1880, when the work was completed. Subsequently the McArthur was laid up at Santa Barbara, and on November 1 Lieutenant Leutze was detached from the Survey, thus closing his energetic and useful term of service on the Pacific coast. The statistics of the hydrography are as follows:

| | |
|---|---|
| Miles run with soundings | 348 |
| Angles measured | 700 |
| Number of soundings | 4,654 |

Lieuts. E. K. Moore and L. C. Heilner, U. S. N., and Masters W. P. Ellicott and R. H. Galt, U. S. N., were attached to the McArthur during this work and rendered efficient assistance.

*Topography near San Luis Obispo, Cal.*—The topography executed by Assistant W. E. Greenwell during the months of May and June, 1881, is comprised in one sheet extending from Point Caballo to Point Buchon, and includes about five miles of shore line. The ground covered is generally of a rocky and broken character.

Work was commenced by a reconnaissance for plane table stations and search for old triangulation points. The sheet includes eight triangulation stations, but of these six were not available for the plane-table work, owing to intervening high ground, and for a portion of the work the remaining two stations were not visible. A large portion of the work was therefore done with the plane table and telemeter alone. The results of this work have, however, proved remarkably accurate, the position of the station Point Buchon, as determined by subsequent triangulation, agreeing within five meters with the plane-table determination. The statistics are as follows:

| | |
|---|---|
| Number of miles of shore line | 10½ |
| Number of miles of road | 3½ |
| Number of square miles, area | 7½ |

As an appendix to his season's report, Assistant Greenwell transmitted to the Office an interesting tabulated statement of the ports Caipicos and Port Harford for the year 1880.

*Tidal observations.*—The self-registering tide-gauge at Saucelito, near the entrance to the Bay of San Francisco, started in February, 1877, has been run without interruption and very successfully by Mr. E. Gray. Prof. G. Davidson, who has been much of the time in charge of the sub-office in San Francisco, has taken great interest in this series of observations, and his large experience in the use of instruments has been of service here in controlling the details of construction and operation. The work turned in has always been of excellent quality, since the first few months of trials and the difficulties of the situation were fairly overcome. It is very desirable that a long series of observations of equal excellence be made at this station.

*Primary triangulation.*—During the summer season of 1880 Assistant A. F. Rodgers was engaged in extending northward the primary triangulation of the California coast from the termination of the work of the previous year.

Owing to extremely unfavorable conditions of the atmosphere, due mainly to the dense smoke caused by extensive forest fires during the early months of summer, the work of observing was greatly retarded.

The party of Assistant Rodgers took the field in July, and on August 5 observations were commenced at Sanhedrin Station. Here, owing to the unavoidable delay caused by unfavorable weather, work was not finished until October 16. The party was then transported to Cahto Station. Observations at this station were satisfactorily concluded on November 18, when the party returned to San Francisco.

Subassistants D. B. Wainwright and J. F. Pratt were attached to the party and rendered valuable assistance in the details of the work. The statistics are as follows:

| | |
|---|---|
| Number of stations occupied | 2 |
| Number of angles measured | 18 |
| Number of observations of horizontal angles | 2,434 |
| Number of vertical angles measured | 15 |
| Number of observations of vertical angles | 855 |

*Primary triangulation.*—The party of Assistant George Davidson resumed the field-work of the primary transcontinental triangulation in June, 1880, and by the end of that month was actively engaged in the occupation of the stations at the ends of the Yolo base-line.

In reference to the atmospheric conditions of the early summer in that region Assistant Davidson reports as follows: "Throughout the Sacramento and adjacent valleys devoted to the cultivation of the cereals the high stubble of millions of acres is burnt between July and the rainy season. In the mountains sheep-herders and stock-herders, hunters and pioneers burn the chaparral and timber for clearing, the air becoming so thick with smoke that it is impossible for weeks to see more than from one to five miles. This smoke ascends to a height of 4,000 and even to 10,000 feet; the smaller height being towards the coast, the larger over the Sacramento Valley."

The plan of work for the season included the occupation of the stations N. W. Base, S. E. Base, Monticello, and Vaca, in the quadrilaterals rising immediately from the base-line, and observations of horizontal angles from these stations upon the five stations Mount Helena, Table Mountain, Mount Diablo, Pine Hill, and Marysville Butte; also observations for latitude and azimuth at each station occupied, and observations of the magnetic elements at one or more stations for the instruction of the officers attached to the party. Vertical angles were to be measured at each station connecting directly with the sea level, and lines of level to be run along the base-line in order to study the best means of overcoming the difficulties on the line; the connection of this leveling of the base with some point, as Woodland, by a line of levels, and thence along the railroad to one of the Coast and Geodetic Survey tidal points on the Bay of San Francisco, was also contemplated, as well as the levelings from Woodland northward to the point where the tangent from Diablo to Shasta touches the earth's surface. It was necessary to build high piers for the instruments at Southeast and Northwest Yolo Base Line Stations, to build the subsurface structures, mark the points, and secure the southeast station by outside references, it being near the left bank of Putah Creek. In connection with these operations it was proposed to make experiments for coefficient of refraction on the line Diablo–Shasta at a point near Colusa, where the line is tangent to the earth's surface or beneath it. It was designed that these observations of simultaneous and reciprocal zenith distances should be made in the early morning for several days at the stations Diablo and Colusa, at such seasons of the year when it might be found possible to occupy Shasta in event of the line proving practicable.

By the close of the season, on December 11, the greater part of the work above mentioned was completed. The portion remaining incomplete relates to the line Shasta–Diablo and the connection of levelings between Woodland and the ocean level for the elevation of the base-line above the sea, although at the date named these were well under way.

In his interesting report for the season Assistant Davidson details fully the methods employed in observing and the nature of the results obtained. He has also made a special report on his observations of the Total Solar Eclipse of January 11, 1880, and a special report for the Board of Engineers for the Pacific coast in reference to the subject of harbors of refuge upon that coast.

Observations were also made to determine the coefficient of refraction between the two stations, Mount Diablo and Martinez, together with the tertiary triangulation to connect those stations. These experiments give a connected series of hourly, simultaneous, and reciprocal double zenith-distances through the twenty-four hours for eight days. They embrace also barometric and boiling-water observations. The difference of elevation was determined by leveling by Assistant Colonna, who referred the work to the Coast and Geodetic Survey bench-mark at Army Point, Benicia.

The officers attached to the party were Assistants Lawson, Gilbert, and Colonna, and Subassistant Dickins. Subassistant Pratt was attached to the party for a month at the commencement of the season; he was then relieved by Assistant Lawson, and directed to join the party of Assistant Rodgers. Much of the success of the season's operations is due to the energetic and harmonious cooperation among the several members of the party. The statistics for the season are as follows:

Triangulation:

| | |
|---|---|
| Horizontal measures in twenty-three positions | 3,371 |
| Pointings of ocular micrometer | 15,546 |
| Signals observed upon | 38 |
| Secondary objects observed upon | 40 |

Azimuth:

| | |
|---|---|
| Observations on twelve nights in twenty-three positions upon Polaris at eastern elongation | 285 |
| Observations on twelve nights in twenty-three positions upon— | |
| I Ursa Minor at western elongation | 288 |
| B. A C 4165 at western elongation | 281 |
| 51 Cephei at eastern elongation | 300 |
| mark for both stars | 974 |
| Ocular micrometer pointings on both stars | 2,318 |
| Ocular micrometer pointings on mark | 3,936 |

Latitude:

| | |
|---|---|
| Total number of observations | 776 |
| Observations for value of micrometer | 549 |

| | |
|---|---|
| Transits: | |
| Total number of observations for transit | 806 |
| Total number of observations for equatorial intervals | 47 |
| Vertical angles: | |
| Total number of observations | 1,113 |
| Leveling: | |
| Number of miles run (repeated) | 15½ |
| Topography: | |
| Length of base for width of one-half mile on each side. | |
| Magnetics: | |
| Number of days on which declination was observed | 12 |
| Number of days on which deflections were observed | 8 |
| Number of sets of deflections | 27 |
| Number of days on which oscillations were observed | 9 |
| Number of sets of oscillations | 41 |
| Number of days on which dip was observed | 3 |
| Number of sets of observations for dip | 14 |

In April, 1881, Assistant Davidson commenced operations preliminary to the measurement of the Yolo base-line. Assistant Colonna visited the locality of the base, and attended to the grading of the line and the building of necessary bridges and supports. The other members of the party were engaged up to June 30 in miscellaneous work having reference to the base measurement and the transcontinental triangulation.

The expedition sent to Point Barrow, in the Arctic Ocean, by the United States Government, for the purpose of making a continuous series of meteorological, tidal, magnetic, pendulum, and other observations at that point, sailed from San Francisco towards the latter part of June under command of Lieutenant Ray. The observers in San Francisco who accompanied the expedition were carefully drilled by Assistant Davidson in magnetic and azimuth observations and the manner of recording tides. Observatories for the use of the party were constructed under his supervision, and all practicable assistance rendered with a view of furthering the objects of the expedition.

*Triangulation and topography.*—With a view to the completion of the triangulation and topography of the coast of California between Walalla River and Point Arena, in Mendocino County, Assistant Sengteller commenced to organize a party on July 1, Mr. Fremont Morse being assigned as Aid. Arrangements being finally completed, the party took the field on July 13; work was begun on the 15th of that month and steadily prosecuted until the close of the season.

While the development of the topography was in progress in the early part of the season favorable opportunities were taken to complete the triangulation left unfinished at the close of the preceding season. Four stations were occupied, and a complete closure effected agreeing satisfactorily with previous results.

The topographical work for the completion of the sheet in the immediate vicinity of the Walalla River was first taken up. Upon this sheet is included Robinson's Landing, a wire cable chute, situated near the mouth of the Walalla River, and entirely exposed to all winds and swells. Here, during the season, a schooner broke from her moorings and was completely wrecked on the beach at the south shore of the Walalla River. The next sheet taken up extends from Haven's Neck to Junction triangulation station, the latter point being the southern limit of the survey of 1870. This sheet includes three landings, Saunders', Iverson's, and Steen's, and the remains of three others, now abandoned. These landings are exposed to all winds and swells, and are dangerous of approach except under the most favorable circumstances.

About one-half mile westerly of Saunders' Landing a group of rocks, visible only at low water, spring tides, was discovered and determined, and kelp patches, so far as they could be identified, were also located, ranging from one-half to three-fourths mile off shore, and having probably not more than four fathoms of water under them.

The general character of the topography is similar to the work of the two preceding seasons, the shore-lines consisting of precipitous bluffs, backed by a rapidly-rising timbered country. The weather during the season was exceptionally favorable for field-work, being clear and calm. Occasionally the smoke caused by forest fires rendered the work of triangulation impracticable, but this did not retard the topography.

Assistant Sengteller mentions in his season's report the existence of several dangers to navigation north of Russian River, and recommends that they be suitably marked.

Upon the recommendation of Lieut. Col. A. S. Williamson, United States Engineers, Mr. Sengteller was visited by Messrs. G. W. Call and Aaron Schroyer, of Fort Ross, Cal., to confer in reference to the site for a proposed light-house between Point Reyes and Point Arena. For this purpose Assistant Sengteller recommends Salt Point, about six miles to the northward of Fort Ross and distant from Point Reyes and Point Arena thirty-six and thirty-one miles, respectively, being the most commanding point from the northward or southward by reason of its projection seaward.

Before leaving Point Arena, the positions of the new constructions erected at that point since 1870, consisting of a fog-whistle building, tanks, and windmill, were determined on the topographical sheet of that locality, and the shore-line in the immediate vicinity of the light-house was retraced. The results show that the bluff on the south side of the dwelling-house and the "blow-hole" in front of the light near the fog-whistle building are gradually washing away.

Mr. Fremont Morse was attached to the party during the season, and rendered acceptable service. The statistics of the work are as follows:

| | |
|---|---|
| Triangulation: | |
| Number of stations occupied | 4 |
| Number of observations | 1,061 |
| Number of angles measured | 42 |
| Topography: | |
| Number of miles of shore-line | 12¼ |
| Number of miles of rivers and streams | 3½ |
| Number of miles of roads, railroads, telegraph, &c | 56¼ |
| Area in square miles | 13 |

*Tidal observations.*—At the request of Mr. W. D. Alexander, superintendent of the survey of the Sandwich Islands, a self-registering tide-gauge was loaned to him for the purpose of securing a series of tidal observations at Honolulu. These observations were commenced in June, 1877, and he has been kept supplied with record paper and blank forms for continuing the series. The results have been transmitted occasionally to the United States Coast Survey Office, and already form a valuable set of records, comparable with those made on the Pacific coast of the United States. Such an opportunity for extending the investigation of the tides of the Pacific Ocean has long been sought by the officers of the Coast Survey.

## SECTION XI.

### OREGON AND WASHINGTON TERRITORY, INCLUDING THE INTERIOR BAYS, PORTS, AND RIVERS.

*Topography, triangulation, and hydrography of the Columbia River.*—Owing to the necessity of repair to the barge Kincheloe, Assistant Cleveland Rockwell was unable to resume the survey of the Columbia River until the 5th of August. At that date the river was still high, the bottom lands being flooded to a depth of three or four feet, and the triangulation points on low ground had all been swept away. These conditions rendering hydrographic work impracticable, Assistant Rockwell necessarily confined his operations to the topography, for which triangulation points were available upon the high ground near Columbia City and Saint Helen's. Work was commenced at Columbia City and steadily prosecuted until the close of the season in November, when the sheet extending from that place to a point several miles above Saint Helen's was completed.

The sheet traverses the river so as to include the channels of Lewis River, Lake River, Willamette Slough, and Scapoosa Bay, and extends to the high lands on both sides of the basin of the Columbia.

The character of the country embraced in the limits of this sheet is somewhat different from that lower down the river, particularly in the vicinity of Saint Helen's, back of which village is a large area of basaltic table-land, nearly flat on its general surface, but much cut up by abrupt gorges and swamp-holes in the solid rock. The surface of this rocky plateau elevated from sixty to one hundred feet above the river is nearly denuded of soil and covered with moss and short grasses, with groves of scrub oak and fir around the ponds and through the swales. On the opposite side of the Columbia, between Lewis and Lake Rivers, are two or three square miles of very low country, consisting principally of mud flats, through which project great numbers of rocky islands of many sizes and curious shapes.

During the season Assistant Rockwell furnished to Lieut. Col. G. L. Gillespie, of the Corps of Engineers, in charge of the river improvements, such data as his party required in making detailed surveys and examinations at various points along the river. The statistics of the season's work are given below:

| | |
|---|---|
| Shore line of river, miles | 56 |
| Shore line of ponds and sloughs, miles | 40 |
| Roads, miles | 139¾ |
| Area of topography, square miles | 21 |

Towards the end of April Assistant Rockwell resumed field-work, and during the early part of the season was engaged in erecting and determining signals for the hydrography. This work was much retarded by unfavorable weather and the necessity for heavy cutting to open lines of sight. During May six days only were available for sounding, owing to continued bad weather. These unfavorable intervals were spent in taking sextant angles and erecting signals. A temporary tide-gauge was erected and observations recorded. In June the triangulation was taken up and six stations were observed upon from Scapoosa Station. The signals destroyed during the previous season were re-erected, and the reconnaissance extended for further work. Soundings were executed on three days. The work done lies between Columbia City and a point one mile above Kalama.

*Special topography of the Columbia River.*—Assistant E. Hergesheimer has continued field and office work for the topographical manual, giving special attention during the first part of the year to the forms of eroded eruptive rocks, as shown in the basin of the Columbia River, making for that purpose a detailed topographical survey of the narrow portion of the Dalles where many of the prevailing type forms are comprised within a comparatively small area. During the season, when the weather at the Dalles was unfavorable for work, Mr. Hergesheimer made a series of views for Coast Pilot use and for the first four maps of the Columbia River. He also made a trip of observation of the topography of the Columbia River Basin as far as Walla Walla, of which he has made a detailed report. His report appears in full in Appendix No. 7 of this report. Returning to California from Oregon, by the overland route, and thence to Washington, D. C., Mr. Hergesheimer inked his survey of the Dalles and views at the mouth of the Columbia River and continued the drawing of sample topography for the topographical manual and the preparation of a new edition of the "Treatise on the plane-table," besides such miscellaneous topographical work as the assistant in charge of the office from time to time required of him.

*Triangulation and topography.*—The triangulation and topography of Port Orchard and adjacent inlets and passages of Puget Sound was continued by Assistant Eugene Ellicott from June 17, 1880, to November 30. It was again resumed early in June, 1881, and was in progress at the close of the fiscal year.

The triangulation of Port Orchard, including Dye's Inlet, Ostrich Bay, and Dogfish Bay, was executed in October and November, 1880. It extends from the south end of Port Orchard northward to a junction at the south end of Admiralty Inlet, with the triangulation executed in 1856.

The topography includes portions of Case's Inlet, Hammersley's Inlet, and Eld Inlet, executed during the season of 1880, and a portion of a sheet of Port Orchard commenced in June, 1881. The statistics are as follows:

| Triangulation: | |
|---|---|
| Number of signals erected | 40 |
| Number of stations occupied | 37 |
| Number of angles measured | 216 |
| Number of angular measurements of six repetitions | 3,756 |
| Number of positions determined | 40 |
| Topography: | |
| Shore line surveyed, miles | 130.3 |
| Roads surveyed, miles | 10 |
| Lines of level (on roads) miles | 9 |
| Area of topography, square miles | 63 |

*Hydrography of Port Discovery and adjacent waters, Strait of Juan De Fuca, W. T.*—The hydrographic work, assigned at the commencement of the fiscal year to Lieut. Perry Garst, U. S. N., Assistant Coast and Geodetic Survey, included soundings in Lower Hood's Canal and the entrance to Hood's Canal and the survey of Oak Bay, Kilisut Harbor, Port Discovery, and Washington Harbor. The schooner Earnest and a steam launch afforded the necessary transportation.

Work in the localities mentioned was commenced in July and steadily prosecuted to the end of the following January, when work was suspended, owing to the necessity for repairs to the steam launch. Operations were again resumed in May and continued until the close of the year. At the end of June all of the work as before mentioned was completed, with the exception of the sheet including Port Discovery and Washington Harbor, which was then well under way. Ensigns S. T. Brown and Henry T. Mayo, U. S. N., were attached to the vessel during the greater part of the year and assisted in hydrography. The statistics of the work are as follows:

| | |
|---|---|
| Number of angles measured | 4,321 |
| Number of soundings | 14,415 |
| Number of miles run with soundings | 598.17 |

*Reconnaissance.*—The reconnaissance for a primary base-line site on the shore of Boundary Bay, in British Columbia, was executed by Assistant Stehman Forney during the months of August, September, and part of October, 1880. The schooner Fauntleroy was used for the transportation of the party. Previous to sending a party to that locality it was deemed proper to obtain the consent of the Canadian Government for making the necessary examinations, erecting signals, and executing other work of the survey on that territory. Application was made accordingly to the proper authorities, and the desired permission was courteously granted, on the condition that in case of consequent damage to private property the owners should be duly reimbursed by the Survey.

On October 15, Assistant Forney was recalled, the necessary funds not being available for a further prosecution of the work, and directed to return to Olympia and thence to San Francisco. At Olympia he remained for a sufficient time to attend to the sale of the schooner Fauntleroy, that vessel being found unfit for further use on the Survey. He arrived at San Francisco in December. Mr. P. A. Welker, aid, was attached to the party during the season and rendered efficient assistance in the work.

As the result of his examination Assistant Forney names three sites as available for a base-line. These are all on the northern shore of Boundary Bay, and within a few miles of each other. The first and most northerly site proposed is over a corduroy road, covered with six inches of gravel, running from Ladner's Landing, on the Frazer River, to New Westminster, B. C. Here a straight line of six and one-half miles can be obtained, but the ground is unstable, and the disturbance is considerable, caused by passing teams. The second site mentioned extends along the delta near the shore of Boundary Bay. A site of five and a half miles can here be obtained, running over ground the surface of which consists of a layer of peat eight inches deep, underlaid by tough clay. The ground here is also reported as being very springy and unstable.

The third site examined by Mr. Forney is situated about three miles south from the second and parallel to it, on the beach near the high-water mark of Boundary Bay. Here a line five and a half miles in length can be measured over a hard sand beach. The measurement of this line would, however, have to be made between the tides, which would never allow more than six or eight hours work on each day.

Assistant Forney reports that the rainy season in this locality usually sets in about the middle of October; that after that time work would be retarded by rain and storms, and that southeast gales have been known to back the tides up to within a mile of the corduroy road proposed as the first base site. This would of course flood the other two sites proposed. The whole delta from Fraser River to Boundary Bay is a peat bog, which during the winter is covered with water, and remains so covered until the rains subside. The houses of the settlers are built upon piles four or five feet above the ground, and the surrounding land is well dyked. Preparations were in progress to run ditches over the whole delta so as to secure drainage.

## SECTION XII.

### TERRITORY OF ALASKA, INCLUDING COASTS, BAYS, AND RIVERS.

*Tidal observations.*—The self-registering tide-gauge taken out to Kadiak, an island on the coast of Alaska, by Mr. W. H. Dall, was put up there at Saint Paul, on a wharf of the Alaska Commercial Company, and has been run continuously by Mr. W. T. Fisher. It was started in August, 1880, and the curves and tabulated results for ten months, which have been received, are satisfactory in appearance.

*Coast of Alaska.*—Data for the Coast Pilot and for enlarging our knowledge of the variation of the compass, and other magnetic elements in Alaska, being greatly needed, Assistant Dall was directed to proceed to San Francisco, and thence to Alaska, the schooner Yukon being assigned to him for this work. At the request of the United States Commissioner of Fish and Fisheries, Prof. Spencer F. Baird, an attaché of the Fish Commission, Dr. T. H. Bean, was permitted to accompany the party on the Yukon, for the purpose of collecting information in regard to the fisheries and material for the United States Census Office.

The party was divided at first. Mr. Marcus Baker proceeded to Sitka on the May steamer, collecting information and making magnetic observations on the way at different stopping places, for which unusual facilities were kindly furnished by Mr. P. B. Cornwall, agent of the steamer, Capt. James Carroll, commanding, and Pilot William E. George. On arriving at Sitka, Mr. Baker found that a party was about to be dispatched by Capt. L. A. Beardsley, U. S. N., commanding the U. S. S. Jamestown, stationed at Sitka, to the Chilcat River (latitude 59° 15′ north, longitude 135° 30′). Mr. Baker was invited to avail himself of the opportunity of enlarging the field of observation by accompanying this party, and accepted. He left Sitka May 20, and returned there on the 5th of June. During this journey in an open row-boat, which was attended with much discomfort from the inclemency of the weather and other causes incidental to such a trip, eight stations were visited and much information gained in addition to that already acquired on the steamer voyage from Portland to Sitka.

The schooner Yukon was dispatched from San Francisco direct to Sitka on the 13th of May by Assistant Dall, who then followed Mr. Baker on the June steamer for Sitka, collecting information for the Coast Pilot, the entire party coming together again at Sitka on the arrival of the steamer, June 7, 1880.

After rating chronometers, &c., the party sailed from Sitka June 16 for Port Althorp, Cross Sound, where observations for position were obtained, showing the charts to be in error to the extent of some ten miles in longitude of that station. From Port Althorp the Yukon successively proceeded to Port Mulgrave; Cook's Inlet (three stations visited); Saint Paul, Kadiak Island; N. W. Harbor, Shumagin Islands; Humboldt Harbor, Shumagin; Dolgoi Island; Belkoffsky; Lisy Island; Unalashka; Saint Paul Island, Pribiloff group; and Plover Bay, Eastern Siberia, where chronometers were rated and magnetic observations made. The Yukon then proceeded through Bering Strait into the Arctic Ocean, stations being selected at Cape Lisburne, Icy Cape, and at Port Belcher. At this last station the pack-ice was met, preventing the party from reaching Point Barrow as had been intended, and the Yukon was directed southward, touching at Kotzebue Sound and obtaining observations off Cape Krusenstern. These observations on the Arctic coast were very important, showing a large discrepancy between the magnetic variation actually observed and that recorded on the latest charts of this region.

On the 5th of September a hydrothermal section of Bering Strait was successfully accomplished. On the completion of it shelter was sought from a gale in Port Clarence, where a station was occupied. On the 10th of September a station was successfully occupied on one of the Diomede Islands, Bering Strait, thus determining the longitude of the meridian separating the American possessions from those of Russia. Plover Bay was then revisited, and the Yukon proceeded to Saint Lawrence Island, where bad weather prevented a landing being made; to Saint Matthew, where observations were secured in the face of great difficulties. From this time the weather became excessively stormy, and after two weeks of incessant gales, being blown away from the entrance to Unalashka Harbor and narrowly escaping shipwreck, the Yukon finally obtained shelter in Chernoffsky Harbor, Unalashka, during a gale which depressed the barometer to 28.25 (the lowest ever recorded in this region) and kept it below 29 inches for several days. Observations of importance were secured at Chernoffsky placing that port some twenty minutes of longitude west of its position on the charts. Unalashka Harbor was reached October 6, and the Yukon sailed for San Francisco October 18, and reached San Francisco November 6, after a stormy and tedious passage. During the season the party traveled some 12,000 miles and occupied forty-two stations, at which sixteen thousand observations of different kinds were made, and sufficient materials for a magnetic chart of the Alaskan region were obtained.

## SECTION XIII.

### KENTUCKY AND TENNESSEE.

*Astronomical.*—As mentioned under the head of Section II, Mr. Edwin Smith, before taking the field for telegraphic longitude work, proceeded to Greenville, Miss., to determine the azimuth of the base measured near that place by Assistant C. H. Boyd. After the completion of that work, Mr. Smith went to Louisville, Ky., and determined the azimuth of the base measured during the preceding season by Assistant G. A. Fairfield.

When this work was finished, Mr. Smith returned to Washington, D. C., to arrange for the operations of the coming season. He was assisted at Greenville and Louisville by Mr. Carlisle Terry, jr., Aid.

*Reconnaissance in Kentucky.*—Field operations in Kentucky were resumed early in July. Mr. C. Schenk in charge, devoted the season principally to a thorough examination of the country lying between the measured base near Louisville and Salt River, for the purpose of determining the most economical plan to reach the line Riley-Mountain Top, which was the indispensable geodetic base for the Kentucky scheme heretofore laid out. After the erection of high tripods at Williams and Prospect Stations, and the exhaustion of all the methods known in reconnaissance to test the intervisibility of points, it was finally ascertained that the line connecting the two stations was impracticable.

Under these circumstances, Mr. Schenk examined in detail the escarpment on the Indiana side of the river, and finally succeeded in finding an intermediate station which would complete the quadrilaterals terminating on the desired base. After the settlement of this question, the different stations were marked and described; tripod signals were erected at two of the stations, and a reconnaisance was made to Jeptha. Field-work was suspended toward the close of November. Mr. Schenk was confined to his room by sickness for about a month in the middle of the season.

*Triangulation in Tennessee.*—In the last Annual Report it was stated that at the close of June Professor Buchanan was making observations from the capitol building at Nashville, for the purpose of connecting the astronomical station in the University grounds with the scheme for the Tennessee triangulation. During the season commencing July 1, Professor Buchanan completed the series of observations referred to above; occupied and finished three other stations, Bennett, Short Mountain, and Hall; and re-occupied Jennings to obtain the direction to Bennett, and to a new station designated Apple. About the middle of the season he erected two additional tripod signals, one at Apple, and the other at Mount Lore. The quadrilaterals so far formed are of excellent proportions, and the checks well distributed. The longest line observed was about 41 miles. Heliotropes were necessary for some of the lines. The field-work was closed and the party disbanded on October 12. The operations of the season connected the astronomical stations of Nashville and Lebanon. Field statistics:

| | |
|---|---|
| Signals erected | 2 |
| Stations occupied | 5 |
| Directions determined | 25 |
| Horizontal observations | 827 |
| Vertical angles | 25 |
| Vertical observations | 860 |

Work was again resumed in June, and the reconnaissance was extended before the close of the fiscal year.

## SECTION XIV.

### OHIO, INDIANA, ILLINOIS, MICHIGAN, AND WISCONSIN.

*Triangulation in Ohio.*—Prof. R. S. Devol resumed the reconnaissance for the extension of the triangulation in Ohio on July 1, and closed the field-work on September 4. On the 6th he returned to his duties as professor of mathematics in the university at Athens.

It was intended to have continued the scheme northwardly from Columbus, but the flat and heavily-timbered lands of Franklin, Delaware, and Morrow Counties rendered this direction impracticable, except at very great expense. Hence, taking advantage of the hilly region near the western sources of the Muskingum River, Professor Devol started from a line established during the preceding season in Licking County, about twenty-five miles east of Columbus, and from that base worked northwardly, laying out a scheme as far as the southern boundary of Huron County. Here, again, the knobs and other elevations ceased; and after a thorough examination of the intervening thirty miles to Lake Erie, he was forced to the conclusion that a connection with the lake could be made only by the employment of unusually high tripods and scaffolds. It should be added, however, that in his belief the triangulation may be continued east or west from the present termination of the scheme in Richland County.

The net-work of proposed geodetic points laid out this season consists of twelve stations, forming six quadrilaterals, with sides varying in length from seven to twenty-one miles.

*Astronomical.*—In the spring of 1881, Assistant G. W. Dean, with Mr. F. H. Parsons as Aid, was occupied in visiting and erecting astronomical observatories at several points, preparatory to continuing the regular determinations for telegraphic longitudes.

Near Cincinnati, Ohio, a site for the observatory was selected at a locality about seven miles from the city, and in the vicinity of Mount Lookout. Before leaving Cincinnati arrangements were well advanced for the favorable prosecution of the longitude work. These operations were greatly aided by the facilities afforded by the Western Union Telegraph Company, who furnished labor and material for the connection by telegraph of the new observatory with the main lines of wires running into Cincinnati.

*Magnetic observations.*—In carrying out the regular scheme of magnetic observations in Section XIV, Subassistant J. B. Baylor determined the three magnetic elements and the approximate geographical position of his stations at the following places: In Ohio, at Cincinnati, Athens, and Cleveland; in Michigan, at Grand Haven, Mackinac, Sault Ste. Marie, and Ontonagon; in Wisconsin, at Superior City; in Indiana, at New Harmony, Indianapolis, Richmond, and Vincennes.

*Triangulation in Indiana.*—The reconnaissance for the triangulation of Indiana was resumed by Prof. J. L. Campbell early in July, and continued until October 20.

Starting from the line McCarlin–Irvington, in the vicinity of Indianapolis, the country to the northward as far as the boundary of Michigan, a distance of one hundred and twenty-six miles, was carefully examined, and a preliminary net-work of triangles laid out, terminating on a proposed site for a base of verification, near the northern boundary of the State. The scheme consists of twelve quadrilaterals and one heptagon, with sides varying in length from six and one-half to nineteen and one-half miles. On that part of the above route lying between Castleton and the

Wabash River a second series of quadrilaterals, eight in number, was located further to the eastward and along the line of the Indianapolis, Peru and Chicago Railway; and this special series is preferred by Professor Campbell, on account of the facilities for transportation.

The country over which the reconnaissance extended was found to be generally level, there being no dislocations of strata by upheavals, and consequently no elevations except such as are produced by the action of surface water. Moreover the land is covered with a forest of high trees. The selection of points was made chiefly by careful barometric observations for differences of heights, in connection with a study of the water-courses. The only method to be adopted in a section of country of the character described is the erection of high signals and observing tripods, the average height of which, according to Professor Campbell, must be about one hundred feet.

*Triangulation and reconnaissance in Illinois.*—At the outset of the fiscal year the continuation of the primary triangulation eastward along the Thirty-ninth Parallel in Illinois was intrusted to Assistant G. A. Fairfield.

It was arranged that the reconnaissance should at the same time be continued to the eastward by Assistant F. W. Perkins, from the terminal points of the scheme previously adopted. The preliminary arrangements having been made in June, field-work was well under way by the 1st of July. The whole of that month and a portion of August were spent in the erection of the necessary tripod signals.

The actual work of observing was commenced on August 13, at the station Clarke's Mound. After this the stations Sugar Loaf and Turkey Hill were occupied. On October 21, Mr. Isaac Winston, Aid, who had rendered efficient service in the party, was detached and ordered to duty in the leveling party of Assistant Andrew Braid on the Mississippi River, and at the same time Assistant Perkins was ordered to close his reconnaissance and to join the party of Assistant Fairfield for the continuance of the triangulation.

Observations at Turkey Hill were completed on November 6. Observations at Dreyer, the next station occupied, were delayed by unfavorable weather, and were not closed until the 6th of December, when operations were suspended for the season.

The weather during the early part of the work was generally favorable, but during the months of October and November observations were much retarded by unfavorable conditions of the atmosphere. On October 15 a very severe gale of wind, accompanied by rain, set in and continued for nearly three days. In this gale the tripod and scaffold signal at Geoffry and the lofty gas-pipe pole at Parkinson signal were blown down. Observations of double zenith distances were made throughout the season upon as many signals as practicable. The statistics of the work are as follows:

| | |
|---|---|
| Number of tripod and scaffold signals erected | 7 |
| Number of stations occupied | 4 |
| Number of primary signals observed upon | 7 |
| Number of secondary objects | 17 |
| Number of observations for horizontal directions | 1,269 |
| Number of observations for vertical angles | 566 |

The reconnaissance executed by Assistant Perkins between July 11 and August 11, and between August 27 and October 24, was successfully carried from the points Hoile and Geoffry to the Wabash River, including about one thousand eight hundred square miles of country. The topography of the State of Illinois along the Thirty-ninth Parallel is very uniform. Between the bluffs east of the Great American Bottom and the Kaskaskia River the surface is slightly rolling, but east of the Kaskaskia it is nearly level, except where the streams in their southerly course have swept away the light soil, leaving wide flat valleys or bottom lands.

Previous to commencing the reconnaissance, Assistant Perkins collected all available information in regard to heights, &c., throughout this region. The best maps of the country were then obtained, and upon them the watersheds were approximately laid down. Trial figures were then laid out, the points to be occupied resting upon the dividing ridges and the centers of the longer lines made to fall in the river and creek bottoms. The highest land near each of these trial points was then found, its approximate height above the sea level determined, and an examination made of the country lying between any two of these trial points. From the data thus obtained, the height of signals required at either end was computed, and any necessary changes made. After this the accuracy of the results was tested by observing from temporary signals. Thirteen primary points were thus selected. Of these, two had been occupied by officers of the United States Engineer Corps in 1879.

Provision has been made for connecting this scheme with that of the Engineer Corps, which extends southward from the Lakes, and with the base line measured by them in Jasper County.

*Triangulation in Wisconsin.*—Field-work in Wisconsin was commenced early in July and was closed by November 1. The report of Prof. J. E. Davies for the season shows a very satisfactory progress in the geodetic work. Four stations were occupied—Harker, Waldwick, Gratiot's Grove, and Sherrell. At the last two stations observations for an astronomical azimuth and latitude were made. The general progress sketch will show the localities of the work, and the following statistics its character and amount:

| | |
|---|---|
| Observing scaffolds and tripods erected | 4 |
| Signals erected | 6 |
| Stations occupied | 4 |
| Pointings for horizontal angles | 4, 656 |
| Repetitions for vertical angles | 684 |
| Stations occupied for time, azimuth, and latitude | 2 |
| Measurements for azimuth | 480 |
| Pairs of stars for latitude | 81 |

*Magnetic observations.*—At the Madison Observatory the annual magnetic observations for absolute values were made by Mr. David Mason, who occupied for several days two of the old stations. The differential observations were continued by Mr. Mason until November 11, 1880, when he resigned and Dr. J. E. Davies took temporary charge of the observatory. In consequence of this change some interruptions took place, in part due to difficulties in the illumination and chemical process, and in part referable to the instruments requiring readjustments. In consequence, Mr. Werner Suess was dispatched in May, 1881, to the observatory to rectify existing defects, and since Dr. Davies' engagements with the university and the Coast and Geodetic Survey would not permit him to devote the needed time to the observatory, Mr. G. W. Suess was placed in charge of it on May 17, and continued to the close of the fiscal year.

## SECTION XV.

### MISSOURI, KANSAS, NEBRASKA, IOWA, DAKOTA, AND MINNESOTA.

*Primary triangulation.*—At the commencement of the fiscal year, Subassistant H. W. Blair was in the field engaged in the extension westward of the primary triangulation in Missouri. The station first occupied was High Point. On the 10th of July Assistant F. D. Granger joined the party. He co-operated in the work until observations at that station were completed on July 18, when he assumed charge of the party, Mr. Blair being transferred to office duty in Washington.

In addition to High Point, six other stations were occupied during the season, namely, Hunter, North Base, Hughes, Heard, Cole, and Hubbard, in the order given. The first, Hunter, was also occupied astronomically. At this station seven primary and two secondary objects were observed upon. For latitude twenty-three pairs of stars were observed upon five nights. Azimuth was also observed and referred to North Base.

On August 14 the camp was moved to North Base, and observations were begun August 16 upon seven primary signals. Work at this station was closed on August 31, when the party was transferred to Hughes, a few miles west of Versailles, Morgan County. The signal at Hughes being over one hundred feet in height and built of two-inch planking, its occupation was attended by considerable difficulty. These were, however, overcome by the use of guys and canvas screens for the protection of the tripod. Fine weather facilitated the work of observing, and the field computation gives good results for the work at this station.

On account of the height of the signal at Hughes and its exposure to injury, it was deemed advisable to close all observations on that station before occupying the stations Hubbard and Cole. The line from Heard to Hughes requiring the full height of the signal at the latter station, the party was moved to Sedalia on the 28th of September, the camp equipage being left at Tipton, near Cole. At Heard the only primary points to be observed upon were Hubbard, Hughes, and Schnackenberg. Work at Heard was completed on October 7, and on the 8th the party and camp were transferred to Cole. This station was occupied from October 12 to 25. The observations of horizontal directions and micrometric differences at Cole were made by Mr. Carlisle Terry, and the zenith distances by Mr. T. P. Borden.

By October 29 camp was transferred to Hubbard, and operations commenced. Mr. Terry was then detached from the party and ordered to report to Assistant C. H. Boyd, at Greenville, Miss.

Observations at Hubbard were closed on November 16, when the party was disbanded.

Mr. Carlisle Terry, jr., and Thomas P. Borden have been mentioned in connection with the party. Their service was marked by faithful and intelligent work, contributing greatly to the advancement of the triangulation. The general statistics of the season's work are appended.

| | |
|---|---|
| Number of stations occupied | 6 |
| Number of observations, horizontal directions | 2,974 |
| Number of observations for micrometer differences | 1,313 |
| Number of observations for zenith distances | 242 |
| Number of observations for time (pointings) | 576 |
| Number of observations for latitude | 238 |
| Number of observations for azimuth | 276 |

*Magnetic observations.*—In continuation of the magnetic survey, Subassistant J. B. Baylor determined the three magnetic elements and the approximate geographical position of his stations at the following places: In Minnesota, at Brainerd, Glyndon, Fort Snelling, and Heron Lake; in Dakota, at Pembina, Jamestown, Bismarck, and Yankton; in Nebraska, at Omaha; in Iowa, at Dubuque.

On December 14 Subassistant Baylor closed field operations and returned to Washington with the records and computations of his season's work.

## SECTION XVI.

### COLORADO, NEW MEXICO, ARIZONA, UTAH, AND NEVADA.

*Primary triangulation eastward along the Thirty-ninth Parallel in Nevada, and magnetic observations.*—At the opening of the fiscal year, Assistant William Eimbeck was engaged in the occupation of Carson Sink Station in Nevada, for the extension eastward of the primary triangulation based upon the great Davidson quadrilaterals. The elevation of this station is approximately nine thousand feet above the level of the sea. Heliotropes were stationed at Cory's Peak, Mount Callahan, Arc Dome, Genoa Cone, and Pah Rah, and the usual observations were recorded for horizontal and vertical angles, and also for latitude, time, and azimuth.

Numerous secondary and tertiary points were observed upon. After the conclusion of observations at Carson Sink, the party was transferred to Arc Dome, the highest peak so far occupied along the thirty-ninth parallel, being about twelve thousand feet above the sea. Here work was retarded by smoke and haze, but a good series of observations was finally secured.

At Lone Mountain, the last station occupied during the season, observations were completed on December 6, and the party was then disbanded.

During the winter Assistant Eimbeck was engaged in computing the results obtained during the season.

Early in the following spring Assistant Eimbeck was instructed to commence a series of magnetic observations at points in California, Nevada, and Utah Territory. This work was begun on the 28th of March, and successfully prosecuted until the latter part of May. The three magnetic elements, and the approximate geographical positions, were determined at seventeen stations between San Francisco and Salt Lake City, and the stations occupied were marked and described for future reference.

In June arrangements were made for resuming the work of triangulation. The station at Mount Callahan (about nine thousand feet above the sea) was prepared for occupation, and observations were under way at that station at the date when this report closes. Mr. Eimbeck was assisted in all his work by Mr. R. A. Marr, Aid, who performed his duties very acceptably.

*Primary triangulation eastward from the El Paso Base.*—Having been directed to resume the extension of the triangulation in Colorado eastward from the El Paso base-line measured by him during the preceding season, Assistant O. H. Tittmann proceeded to Colorado Springs towards the end of June, 1880, and there organized a party for that work.

At the close of the preceding summer a line of levels had been partially completed between the West Base monument of the El Paso Base and the track of the Denver and Rio Grande Railroad at Colorado Springs. The first operation of the season was to finish this work. The height of Colorado Springs is determined by a line of railroad levels from Denver, the elevation of which point above the mean tide of the Atlantic is known with considerable accuracy from a combination of railroad levels.

The work of observing horizontal angles was commenced at the station Holcolm Hills on July 1, and continued at that station until the 15th of August. Much difficulty in observing was experienced, owing to the prevalence of high winds. On account of the vibration of the elevated observing scaffold, due to this cause, it was deemed advisable to use the method of repetitions instead of directions in observing the angles at this station. Between August 18 and September 29 three additional stations were occupied, viz, Big Springs, Cramer's Gulch, and Square Bluffs.

The observations at the succeeding station, Holt, were delayed by unfavorable weather, beginning on October 10 with a snow storm, which lasted with severity for three days. The next station, Hugo, was reached on the 21st of October, and after two additional signals had been erected to the eastward the necessary angles were measured. A subsidiary station was established and occupied to the northwestward of Hugo Station, by means of which several houses in the town of Hugo were connected with the triangulation, and soon after the party was disbanded. At all the stations both horizontal and vertical angles were observed. Owing to the fact that the signals were in general visible only early and late, the vertical micrometric differences of zenith distances could be measured only at the times of day during which the refraction is supposed to be most variable and uncertain. Nevertheless the coefficient of refraction deduced from the reciprocal observations of vertical angles gives remarkably small values, ranging from .02 to .05.

Messrs. John E. McGrath and G. F. Bird, Aids, rendered acceptable service in the party during the season.

## COAST AND GEODETIC SURVEY OFFICE.

In the operations of the office, of which as heretofore I have had special charge, while the speedy discussion and publication of field results has been kept steadily in view as one of the main objects of its organization, careful attention has been given during the year to the extension of mechanical facilites, to the study of improved forms of instruments of precision, and to experimental researches involving the determination of physical constants applicable to the processes of geodesy.

Assistant Edward Goodfellow rendered aid throughout the year in executive duty, and in the preparation for publication of the annual reports.

In order to meet the increased demand for maps and charts, it became necessary to enlarge the printing office by the building of an annex, and the establishment of a new press of large size; this work was completed and the new press in operation early in December.

The adaptation of a room in the northeast part of the basement of the office for comparisons of base-bars was completed according to the plans of Assistant Schott. In this room were built up from the ground the brick piers and supports for the meter bars, standards, and comparators; a new floor was laid, isolated from the piers; sudden changes of temperature were guarded against by double sashes to the windows; uniformity in the temperatures of comparison was maintained by immersing the bars in a tank filled with glycerine, and connected with a heating and cooling apparatus. The tank was arranged to be moved easily and rapidly upon frames or carriages running over iron rails.

These facilities were made available for the comparisons for the determination of length of the new five-meter primary base apparatus, the construction of which, as designed by Assistant Schott, was completed in June, 1881. A full account of these comparisons with descriptions of the methods and apparatus employed has been deposited in the archives.

The work accomplished may be summarized as follows:

1. The construction of five steel meters with platinum-iridium contact ends, and the comparisons of each of these meters with the standard meter of the survey—the committee meter of 1799.

2. The determination of the coefficient of expansion of each meter.

3. The comparison of the two five-meter standard steel bars with the joint length of the five meters.

4. The determination of the coefficient of expansion of the two five-meter standards.

5. The comparison of the bars of the five-meter base apparatus.

6. Determination of the constants of the Bessel–Repsold comparators (Nos. I and II), and of the Fauth & Co. screw level comparators (Nos. III and IV) and observations for scale values, and determination of the corrections of the thermometers used in the comparisons.

It may be here stated that a comparison will be made between the six-meter iron standard, upon which depend the primary base lines heretofore measured, and the joint length of one of the new five-meter standards and one of the single meters.

These operations having been completed, on the 25th of June the new base apparatus, after inspection by the Superintendent, was packed for transportation to California, where its practical working qualities will be tested in the measurement of the Yolo Base.

Improvements already made, and others projected in the circular graduating engine, demanded increased space and a more steady water power for their proper application; hence a room of larger size adjoining the comparing room was carefully prepared for it, and the supply of water maintained by a reservoir upon the floor above. The engine was mounted in Room No. 7 upon a foundation of a substantial character specially built for it. Its automatic part was arranged so that as soon as the last line of any graduation was cut the water was shut off and the motion stopped. In order to secure a uniform temperature of 98° F., which is the temperature of graduation, an automatic heat regulator was devised to limit the amount of gas to be burned for heating purposes. Much time was also given to the consideration of the best method of obtaining an automatic arrangement for the correction of the errors of graduation. The centering apparatus was greatly simplified, and its working is now entirely satisfactory. The plans for these improvements were devised by Mr. Saegmuller, chief mechanician, in consultation with myself, and for their successful execution much credit is due to him.

Mr. Saegmuller's "solar attachment" to the ordinary surveyor's transit deserves mention here. It consists of a second telescope mounted upon an axis perpendicular to the main telescope and provided with a level by which the parallelism of the two telescopes may be readily determined. The smaller telescope having been set so that the angle between the two is equal to the declination of the sun for the time of observation, the transit telescope can then be set to the latitude of the place, and by turning the two telescopes independently of each other on their respective axes the sun can be brought into the field of view of the small telescope, and the larger telescope will then be in the plane of the meridian. When these successive adjustments have been carefully made the true azimuth of the sun can be determined within one minute of arc, a degree of accuracy much greater than can be reached with the ordinary solar compass.

During the year I availed myself of the aid of several field officers, temporarily assigned to office duty, for the prosecution of investigations relating to the operations of the survey.

Assistant G. A. Fairfield, upon reporting at the office about the middle of March, began the collection of material available for the prosecution of his field-work during the coming season, and familiarized himself with the practical working of the instruments to be used. Towards the end of April he was detached to take charge of a primary triangulation party.

Assistant E. Hergesheimer reported for office duty in May, and was directed to take up the preparation of a "treatise on the plane table." He studied, in relation to this, the best mode of dividing telemeter rods, making a series of comparisons of the results of telemeter and micrometer distance measures. Towards the end of June he was assigned to the charge of the office division of topography upon its prospective organization during the early part of the ensuing month.

Assistant S. C. McCorkle, upon his assignment to office duty in February, began an examination of the topographic sheets registered in the archives, with special reference to their need of repair, amendment of titles, and condition of completeness in conformity with the present requirements of the Survey. He had examined upwards of eleven hundred sheets up to the time of being detached for field-service in the month of June.

Assistant J. J. Gilbert reported for office duty in January, and was assigned to the computing division. He remained in the office till early in May, and, when not occupied in computing, aided Mr. Schott in the comparison of standards and base-bars.

Assistant F. W. Perkins was attached to the office during February, March, and April, and was occupied in an examination of theodolites Nos. 15, 16, 93, and 100; in making plans and estimates for tripod and scaffold signals; in making a series of practice observations for time and latitude, and in the collection and preparation of material for the field-work which he took up in the month of May.

Assistant O. H. Tittmann, upon his assignment to office duty in January, was directed to examine the records of explorations of the Gulf Stream, made under instructions from Superintendent A. D. Bache, with a view of preparing for publication the results already compiled, and such others as need compilation. Mr. Tittmann completed this work towards the close of March, and during April made such special investigations as were from time to time intrusted to him. In May he began a description of the methods of precise leveling as followed in the Survey, and finished it before taking charge of a field-party in June.

Assistant Edwin Smith, soon after reporting for office duty in October, made a series of comparisons of the stop-meter of the Saxton dividing-machine with the committee meter, and then prepared a room for the reception of standard balances. He weighed and adjusted a number of the brass kilograms and half kilograms intended for distribution to the States, and computed results of the final weighings; tested the new Troemner half kilogram balance; revised papers received from the Warden of the Standards, London, containing record of the weighings of the United States Arago platinum kilogram with the Miller kilogram, and the determination of the density of the former; compared six new steel yards; compared the Rogers provisional bronze yard with the United States standard yard bronze No. 11, and, with the aid of Prof. W. A. Rogers, of Harvard College Observatory, made comparisons of bronze yards (Pratt & Whitney Nos. 1 and 2) with standard yard bronze No. 11. Before leaving the office for the field, early in March, he prepared the telegraphic longitude instruments for field use.

Assistant Andrew Braid reported at the office in May, and was directed to make a series of observations for the determination of the coefficient of refraction upon lines of level over the Potomac River. He deduced the results of these observations, computed the leveling work between Athens, Ohio, and Mitchell, Ind., and determined the inequality of pivots of micrometer levels Nos. 2 and 3.

Subassistant H. W. Blair, upon reporting for duty about the middle of August, was employed in a comparison and examination of standards, and in a revision of records and reductions relating to comparisons of weights and measures. He also informed himself fully in regard to the plans for a new base apparatus, and prepared himself for assisting Mr. Schott in its construction and verification. In this work, and in the comparisons of the standards and base-bars, his time was chiefly occupied. He made intercomparisons of Kew Fahrenheit thermometers Nos. 966, 967, 968, 969, 970, 971, 18411, and 21467; compared the Saxton stop-meter with Berlin brass meter No. 49 and with the Arago platinum meter, and attended to some general work relative to standard weights and measures, including the standarding of a set of alcoholometers for the Internal Revenue Office. In June, having completed the work assigned to him in connection with the construction and comparison of the new five-meter primary base apparatus, Mr. Blair was ordered to field-duty.

Mr. F. H. Parsons was engaged upon-office work from the beginning of July till the close of February. He compared the six-meter base-bars Nos. 1 and 2, and 3 and 4; also the four-meter secondary base-bars Nos. 9 and 10, and duplicated the record of these comparisons; compared twelve thermometers with the standard; examined and adjusted two spring governor chronographs, examined twelve-inch theodolite No. 131; compared sixteen gauges for the Ordnance Office; compared four-meter base-bars Nos. 5 and 6, and computed results of the comparisons; examined the graduation of the limbs of theodolites Nos. 29, 98, 132, and 133, and assisted Mr. Blair in the comparisons in which he was engaged, and in the determination of the value of the screw of the Hilgard field lever comparator No. 3. On the 1st of January he was assigned to duty in the computing division.

Mr. E. D. Preston was employed upon special office-work during the months of July, August, and September. He compared secondary base-bars Nos. 1 and 2 with the standards; re-examined theodolite No. 107; reviewed a report upon the densities of the waters of Chesapeake Bay; made an examination of the Troughton & Simms vertical circle No. 46, after its re-graduation; aided in the comparison of base-bars 3 and 4, and 9 and 10, and made an examination for eccentricity of theodolite No. 130. On the 29th of September he was assigned to field-service.

Mr. W. B. Fairfield, on office duty during April, was employed in aiding Mr. Saegmuller in bringing up the record of instruments, and in testing the action of the graduating engine after it had been established in its new position.

*Hydrographic Division.*—Capt. E. P. Lull, U. S. N., was on duty as hydrographic inspector until December, when he was relieved, and succeeded by Commander C. M. Chester, U. S. N. The services of these officers in their immediate relations to the hydrographic parties have been elsewhere referred to in this report; they had also the supervision of the work of the hydrographic draughtsmen in the office, with the aid of Lieut. C. T. Hutchins, U. S. N., who was on duty during the whole of the fiscal year.

The labors of the draughtsmen in this division may be summarized as follows:

Mr. E. Willenbucher, hydrographic draughtsman, protracted, plotted, or drew eighteen hydrographic sheets; plotted deep-sea soundings off the Atlantic Coast from Cape Cod southward, and deep-sea soundings in the Caribbean Sea and vicinity of the West India Islands; verified the drawings of four coast charts, and the drawing of all hydrographic sheets plotted during the year; made projections for hydrographic parties, and tracings to meet special calls for information.

Mr. W. C. Willenbucher, hydrographic draughtsman, protracted, plotted, or drew sixteen hydrographic sheets; transferred and plotted deep sea soundings of charts of the Caribbean Sea for the Hydrographic Office; verified the drawing of the chart of "Approaches to Blue Hill Bay," and selected outside soundings for engraving on that chart; attended to additions and corrections on the sketches showing progress of the hydrographic work, and made tracings to meet special calls. He was on duty with hydrographic parties during portions of the year, aiding in the hydrographic survey of Chincoteague Bay from July 10 to September 30, 1880, and in that of Chincoteague Shoals from June 3 till the close of the fiscal year.

Mr. F. C. Donn, hydrographic draughtsman, verified, inked, and finished five hydrographic sheets, reduced soundings upon four hydrographic sheets, and plotted and finished them; executed miscellaneous work of tracing, lettering, &c., and aided in the preparation of authorities and dates for the table of depths.

Reports from the chiefs of the computing and tidal divisions and the drawing and engraving divisions of the office are appended; in these are given full statements of the work performed in these divisions during the year. In Appendix No. 3 will be found a list of information furnished by the office in reply to special calls during the year; this list has been compiled from the monthly reports of the computing, tidal, and drawing divisions. A general summary of the work begun, completed, or in progress in the drawing division appears in Appendix No. 4, and a similar summary for the work of the engraving division in Appendix No. 5.

*Electrotyping and Photographing Division.*—Dr. Zumbrock, in charge of this division, made during the year thirty-two altos and thirty-two bassos from engraved plates, including in this number twelve altos and twelve bassos for the Engineer Bureau, United States Army. The total weight of these plates was sixteen hundred and thirty-six pounds. Seventy-six plates were steel-faced; sixty negatives, three hundred and forty-six prints, and twelve positives on glass were taken.

Dr. Zumbrock kept in order the batteries for the electric clocks and bells used in the office, and made in his laboratory the collodion, the varnish, and many of the chemicals required in his work. He had the aid of Mr. Frank Over.

*Miscellaneous Division.*—There were received from the Public Printer during the year, and placed in charge of Mr. M. W. Wines, chief of this division, the following aggregates of publications of the Survey:

| | Copies. |
|---|---|
| Annual Report for 1876 | 1,839 |
| Annual Report for 1877 | 1,895 |
| Appendices to the annual reports (extra copies) | 5,100 |
| Tide Tables for Atlantic coast for 1881 | 2,000 |
| Tide Tables for Pacific coast for 1881 | 1,000 |
| Catalogue of Charts, edition of 1880 | 2,000 |
| Notices to Mariners, Nos. 27, 28, 29, 30, 31 | 3,000 |
| Atlantic Coast Pilot—subvolumes—showing coast from Boston to New York, second edition | 1,693 |
| Laws and Regulations relating to Coast and Geodetic Survey | 500 |
| Deep Sea Sounding and Dredging | 496 |

There were distributed during the year eighteen hundred and ninety-one copies of the Annual Report of the Superintendent, and six hundred and thirty-three copies of Divisions A and B of the Atlantic Coast Pilot, including subdivisions. Division C, from New York to Chesapeake Entrance, was put to press.

In the chart room, under the immediate care of Mr. Thomas McDonnell, there were received thirty-one thousand one hundred and sixty-two sheets of charts. Of this number four thousand six hundred and forty-six copies were printed from stone. There were published during the year, from engraved plates, sailing chart B, Cape Hatteras to Key West; general coast chart Isle au Haut to Cape Cod (western part); coast charts Penobscot Bay, Key West to Rebecca Shoal, and Tampa Bay, and chart of Tortugas Harbor and approaches; and from stone by the photolithographic process a map of Winyah Bay and Santee River (reprint), and charts of Saint John's River, Fla., from Jacksonville to Lake Monroe (new edition), Mississippi River Nos. $510^{12}$ and $510^{13}$ (new editions), San Diego Bay, Cal. (new edition), Newport Entrance, Cal., Shelter Cove, Cal., Columbia River Entrance and Alseya Harbor Entrance, Oregon, and Sitka Harbor, Alaska (new edition).

Distribution was made of twenty-three thousand seven hundred and fifteen copies of charts, including in this number four thousand eight hundred and eighty-five copies for the use of the several departments of the government, and eleven thousand seven hundred and forty-one copies placed in the hands of sale agents.

The office printing was done by Mr. Frank Moore, with the aid of D. N. Hoover, J. H. Beck, and, during part of the year, J. S. Reilly, W. H. Grabenhorst, and James Smith.

All of the work of the folding room, including the backing of charts, and the preparation of backed paper for field use was attended to by H. Nissen, aided by R. T. Bassett.

There were received and registered in the archives, under the care of Mr. G. A. Stewart, seven hundred and thirty original volumes of records, and four hundred and fifty-nine duplicates, twenty-two topographic and forty-two hydrographic sheets, and one hundred and seventy-eight specimens of sea bottom. The whole number of topographic sheets registered to June 30, 1881, is fourteen hundred and eighty-seven, and of hydrographic sheets fourteen hundred and seventy-four.

The library remained under the immediate care of Mr. Samuel Hein. It received additions during the year of one hundred and ninety-five volumes and four hundred and seventy-nine periodicals.

Mr. G. N. Saegmuller, chief mechanician, had charge of the instrument shop. Allusion has already been made to the improvements suggested or planned by him in instrumental appliances. He had the aid of John Clark, E. Eshleman, P. Vierbuchen, and Louis Fischer.

The wood-work of instruments, their packing for transportation, and all other carpentry work needed by the office was done by Mr. A. Yeatman, with the aid of G. W. Clarvoe, and, during part of the year, of G. F. Cox.

Messrs. W. B. French and C. D. Gedney performed the clerical work of my office, aided during part of the year by Messrs. W. A. Herbert and C. L. Drinkard. Mr. Herbert was transferred to the office of the disbursing agent in October. Mr. Drinkard, who had already rendered acceptable service in the engraving division, had barely entered upon his new duties when he was seized with an illness which proved fatal, greatly to the regret of his associates.

In the office of the Superintendent, Assistant W. W. Cooper rendered acceptable service until toward the close of the fiscal year, when failing health obliged him for a time to retire from active duty.

Respectfully submitted.

J. E. HILGARD,
*Superintendent United States Coast and Geodetic Survey.*

The Hon. SECRETARY OF THE TREASURY.

# OFFICE REPORTS.

## *ANNUAL REPORT OF THE COMPUTING DIVISION, COAST AND GEODETIC SURVEY OFFICE, FOR THE FISCAL YEAR ENDING JUNE 30, 1881.*

COMPUTING DIVISION, COAST AND GEODETIC SURVEY OFFICE,
*June* 30, 1881.

DEAR SIR: In conformity with the regulations of the Survey, I herewith respectfully submit the annual report of work done by the several computers during the fiscal year ending June 30, 1881.

The charge of the Computing Division has been continued with me; in addition to this, I remained charged with temporary duty of a special character, extending over nearly the whole period, as mentioned below.

The changes during the year in the *personnel* of the Computing Division were as follows:

Mr. H. Farquhar was transferred from field to office work and reported for duty October 25, 1880; Mr. C. H. Kummell was assigned to duty November 8, 1880; C. B. Turnbull reported as copyist January 22, 1881, and Mr. C. W. Henderson, as clerk, April 18, 1881. Temporary assistance was given by J. J. Gilbert, Assistant, between January 27 and May 7, 1881; by J. B. Weir, Subassistant, between February 15 and June 14, 1881; by F. H. Parsons, Aid, between January 19 and February 15, 1881; by T. P. Borden, Aid, between January 21 and May 28; by J. E. McGrath, Aid, between January 24 and June 30, 1881; by I. Winston, Aid, between February 15 and June 23, 1881; by G. F. Bird, Aid, between February 23 and June 30, 1881; by F. E. Wiggin, between March 1 and May 19, 1881; by J. B. Boutelle, between April 14, and May 21, 1881.

The Computing Division lost the effective services and experience of Mr. J. Main, who first became connected with the Survey in November, 1851, and continued to discharge his duties until September, 1877, except during a short interruption in 1859, and another between August, 1861, and October 25, 1866, when disconnected from the Survey. In 1877 he was compelled by ill-health to take a temporary rest, resuming his work, at a reduced rate of pay, May 1, 1878; but his health again failed him toward the close of the year 1880, and, in consequence, his connection with the Survey terminated March 1, 1881.

Mr. W. C. Ames resigned his position March 2, 1881.

As special duty I had assigned to me the construction and standarding of a five-meter compensation primary base-apparatus from designs submitted by me, and from working drawings prepared by Mr. W. Suess. This work was accomplished with the assistance of Subassistant H. W. Blair and the aid of Mr. Suess, mechanician to the Survey, by June, 1881. It involved, besides the construction of two base-bars, trestles, comparators, &c., the fitting up of a comparing room, comparisons of five single meters with the committee meter, and the construction of two five-meter standard bars, together with the determination of the coefficients of expansion and length of the various pieces.

Compared with last year a considerable part of the effective force of this division was consumed by two classes of computations, in consequence of their results being required for immediate use, viz, the computation of the tertiary triangulation of the Mississippi River, as far as executed, between Memphis, Tenn., and New Orleans, La., involving base lines and astronomical azimuths in the adjustment; the second kind of computations were those of spirit levelings of precision along the same river between Greenville, Miss., and Carrollton, La. The first operation involves the solution of dozens of normal equations, and the second involves careful handling of a great mass of figures. Other work could, in consequence, receive less attention; still, considerable progress was made in developing the secondary triangulations on the surface of Clarke's spheroid of 1866, adopted by the Superintendent on February 4, 1880, in the place of Bessel's spheroid, hitherto used.

The desirability of a change of the fundamental surface of reference and projection was first distinctly indicated by the result of the combination of the Nantucket and Pamplico-Chesapeake arcs of the meridian and the old Peruvian arc, but, with the extension of the measure of the oblique arc along the Atlantic coast from Maine into Georgia, the systematic discord between the geodetic and astronomical determinations demanded, for its removal, that a suitable change be made in the assumed dimensions and figure of the earth.

No adjustment of telegraphic differences of longitude having yet been made, I subjected to discussion, by application of the method of least squares, thirty-four such determinations, entering into various combinations made between the years 1851 and 1880, and uniting, through intermediate stations, Greenwich, England, and New Orleans, La. The result of this investigation forms now the standard longitude of our triangulations. These adjustments will be extended as the work progresses or new checks are applied.

The work on the Coast and Geodetic Survey Magnetic Observatory at Madison, Wis., has been continued. The photographic traces were read off and tabulated to the end of April, 1881. The operator, Mr. D. Mason, resigned November 11, 1880, and Prof. J. E. Davies undertook temporarily the management of the observatory, but owing to other duties and consequent want of time gave it up, and Mr. G. W. Suess was placed in charge May 17, 1881. In consequence of these changes the work has suffered some unavoidable interruptions, due in part to the instruments having got out of adjustment, and in part to defective photography. To remedy these defects Mr. W. Suess visited the observatory May 22, 1881, and provided for its necessities.

The subject of the secular change of the magnetic declination has received my personal attention, and an improved and greatly enlarged edition (the fourth) of my paper on the secular change of the declination has been brought out. It is illustrated with three plates, and printed as Appendix 9 to the Report of 1879. It contains the latest information on the subject to June, 1881.

An investigation was made of the direction and probable amount of the magnetic declination (variation of compass) in the region supposed to contain the landfall of Columbus on his first voyage to America in 1492, and along his track from Palos, Spain, to Gomera, Madeira Island, and thence to the West Indies. This was accompanied by a computation of his probable track after leaving Gomera.

Special attention was given to the magnetic outfit of the two polar expeditions: the one to Lady Franklin Bay, north of Greenland, the other to Point Barrow, Alaska. Mr. M. Baker had charge of the practical instruction of the observers in the use of the instruments, for which, however, the available time was very limited.

The demand on the office for special information connected with geodesy, practical astronomy, and terrestrial magnetism has been steadily on the increase, and is in proportion with the increased area covered by the operations of the Survey. A great portion of this information is prepared in this division; besides, certain divisions of the office are furnished with data required generally in the production of charts. The examinations of the field records, covering the subjects mentioned above, for completeness and the care of the duplicate records, were continued as heretofore.

The general distribution of the computing work among the computers has not varied greatly from that of last year, Mr. Christie having taken the place of Mr. Main, charged with astronomical latitudes and azimuths; Mr. Kummell has charge of telegraphic longitudes, the other computers of geodesy, and in magnetic computations Mr. Courtenay gave some assistance. Their work is examined and reported on by me, and the results are properly registered, in which shape they are readily accessible for immediate use.

Between October 8 and October 22, 1880, I was placed in charge of the office, during the temporary absence of the Assistant having charge thereof.

The work performed by each computer has been summarized as follows:

Mr. James Main computed the astronomical latitudes of stations, Lum's Point, La., 1880; Lake Providence, La., 1880; and the astronomical azimuths of stations, Lum's Point, La., Lake Providence, La., 1880; Lola, Cal., 1879; Round Top, Cal., 1879; and furnished mean places of stars for field parties.

Dr. Gotlieb Rumpf computed the following secondary and tertiary triangulations, viz: Admiralty Inlet and Puget Sound, W. T.; vicinity of Saint Louis, Mo., 1874; Nisqually to Muck Prairie,

W. T., 1870–'71; Straits of Fuca, W. T., 1870–'71; District of Columbia, 1880 (by McCorkle and Sinclair); north of Punta Arena, Cal., 1878–'79; Fisherman's Bay, Cal., 1879–'80; Laguna Madre, Tex., 1878–'79; and Laguna Madre to Rio Grande, Tex., 1854–'67. He also computed geographical positions, with reference to Clarke's spheroid, of the following localities: Coasts of Maine and Massachusetts, Rhode Island, Long Island Sound, vicinity of New York City, New Jersey, west side of Delaware Bay, Chesapeake Bay, James River, south of Cape Henry, Pamplico River, Pungo River, Neuse River, Magnolia base to Barataria base, Rosario Straits. Revised means of spirit levelings, Mississippi River, Carrollton, La., to Fort Adams, Miss., 1879–'80; tabulated geographical positions, Laguna Madre, Tex., 1879, and rendered some assistance to Major Powell, Chief of the United States Geological Survey.

Mr. Edward H. Courtenay computed magnetic observations made in the Northwest by Subassistant Baylor in 1880; also the magnetic observations (absolute measures) at Madison, Wis., 1880; also the magnetic observations made in the South by Mr. Baylor in 1880, and continued the collection of magnetic instrumental constants. He attended to the registering of the resulting geographical positions, and had charge of the work connected therewith, performed by Messrs. Bird, Borden, McGrath, and Winston; adjusted the main series of triangles, Rosario Straits and Canal de Haro, W. T., 1853–'54–'71; the principal triangles vicinity of Princeton, N. J., 1840–'41, and the principal triangles vicinity of Baltimore, Md., 1863. Supplied geodetic information required by field parties or in reply to general outside correspondence, and arranged one hundred volumes of records and computations, principally the latter, for the binder.

Mr. Myrick H. Doolittle adjusted the primary and secondary triangulation near Savannah River, 1865–'66; computed length of Fort Whipple Reservation base 1880; computed geographical positions of primary triangulation, vicinity of Lake Champlain in New York, Vermont, Massachusetts, and New Hampshire; computed the principal triangulation, District of Columbia, 1880; computed the auxiliary triangles connecting the United States Naval Observatory with Fort Myer, Va., 1881; adjusted the secondary triangulation south of Tybee Light, Ga., to Ossabaw Sound, Ga., 1855–'57–'58, and introduced new measure of the San Pedro base, Cal., into the main triangulation; computed and adjusted the following tertiary triangulations on the Mississippi River: Bayou Sara, La., to Jackson Point, Miss., 1879–'80; Lum's Point, La., to Bayou Sara, La., 1879–'80; Baton Rouge, La., to Bayou Sara, La., 1880–'81; Milliken's Bend, La., to Lake Providence, La., 1880–'81; Vicksburg, Miss., to Lake Providence, La., 1880–'81, and Lake Providence, La., to Walnut Point, Miss., 1880–'81.

Dr. Jermain G. Porter completed the computation of the triangulation of the Mississippi River, Natchez, Miss., to Jackson Bend, Miss., 1879–'80; computed lengths of four base lines on the Mississippi River measured by Assistant Ogden in 1880; computed some secondary positions on the river north of Donaldsonville, La.; computed the triangulation between Iberville, La., and Baton Rouge, La., 1879–'80; revised the triangulation between the Magnolia base, La., and the Head of Passes, La.; computed geographical positions referring to Clarke's spheroid, for preceding work, and to the triangulations of Chandeleur and Isle au Breton Sounds, La.; computed the triangulation near and south of Vicksburg, Miss., 1880; computed the triangulation between Jackson's Bend, Miss., and Vicksburg, Miss., 1879–'80; computed length of base at Greenville, Miss., 1880; computed horizontal directions at stations Lola, Cal., 1879, and Sugarloaf Mountain, Md., 1879; computed preliminary geographical positions of stations of primary triangulation in Nevada, 1878–'79–'80; computed and adjusted main series of the coast triangulation, north of San Francisco, Cal., 1878–'79–'80; revised the astronomical azimuth computation, Greenville, Miss., 1881, and the astronomical latitude computations of El Paso, Colo., 1879, and of Round Top, Cal., 1879, and of Hunter, Mo., 1880; assisted me in the solutions of equations in connection with magnetic work; computed magnetic intensities of Lieutenant Very's observations in Canada, 1880, and checked numerous computations made by me in connection with the making and standarding of the new five-meter compensation base apparatus.

Mr. Alexander S. Christie completed the computation of the spirit-levels Mississippi River, between Greenville, Miss., and Milliken's Bend, La., 1880; computed the spirit-levels Mississippi River, between Carrollton, La., and Fort Adams, Miss., 1880; computed the spirit-levels Mississippi River, between Milliken's Bend, La., and Rodney, Miss., 1880–'81; computed the astronomical latitudes of Sugarloaf, Md., 1879; of Greenville, Miss., 1878; of Baton Rouge, La., 1880; of Atlanta, Ga., 1880; of Louisville, Ky., 1879; and of Round Top, Cal., 1879; revised the latitude computations of El Paso, Colo., 1879, and of Tanyard, Ala., 1878; computed the astronomical azimuth stations Greenville, Miss., 1881; Williams, Ind., 1881, and furnished star places for field parties.

Mr. Henry Farquhar computed the magnetic observations made by Lieutenant Very in Canada, 1880; computed the astronomical latitudes of Prospect Mountain, N. Y., 1878, and of El Paso, East Base, Colo., 1879; computed the spirit-levels Mississippi River, between Point Coupée, La., and Concordia, La., 1880–'81, and made good progress with the computations of the magnetic observations made by Lieutenant Nichols, coast of Mexico, Lower California, and of California, 1880–'81.

Mr. Charles H. Kummell computed the telegraphic difference of longitude between Atlanta, Ga., and New Orleans, La., 1880; computed the telegraphic difference of longitude between Charleston, S. C., and Atlanta, Ga., 1880, and made progress with the computation of the telegraphic difference of longitude between Nashville, Tenn., and Atlanta, Ga., 1879–'80. He also attended to some miscellaneous computations.

Mr. Frank E. Wiggin revised the latitude computations of stations Baton Rouge, La., Greenville, Miss., Louisville, Ky., Atlanta, Ga., and Sugarloaf, Md.; computed the latitude of Tanyard, Ala., 1878; computed the astronomical azimuths needed in connection with the magnetic declinations observed in 1880 by Subassistant Baylor, and computed the telegraphic difference of longitude between Louisville, Ky., and Nashville, Tenn., 1879.

Temporary assistance was given to the computing division by the following named persons:

J. J. Gilbert, Assistant Coast and Geodetic Survey, made out horizontal directions stations Round Top, Cal., 1879, Great Caspar, Cal., 1878–'79, and Two Rock, Cal., 1879, and assisted in the comparisons connected with the standarding of the new five-meter base bars.

J. B. Weir, Subassistant Coast and Geodetic Survey, computed the spirit-levels between Hagerstown, Md., and Bloomington, W. Va., 1878.

F. H. Parsons, Aid, Coast and Geodetic Survey, computed tertiary geographical positions on the Mississippi River, assisting Dr. Porter, and assisted in the comparisons connected with the preparation of the near 5-meter base bars.

T. P. Borden, Aid, Coast and Geodetic Survey, computed secondary geographical positions of Currituck Sound, N. C., on Clarke's spheroid; also for coast stations between Cape Henry, Va., and Cape Hatteras, N. C., and for some stations in Pennsylvania. After the resignation of Mr. Ames, he acted as clerk to the computing division.

J. E. McGrath, Aid, Coast and Geodetic Survey, was engaged in reading off and tabulating results of magnetic traces, Magnetic Observatory, Madison, Wis., from March 1880, to May 1881; computed some geographical positions on Clarke's spheroid, and assisted as recorder in the comparisons of the new base bars. He also attended to some miscellaneous copying.

I. Winston, Aid, Coast and Geodetic Survey, computed secondary geographical positions on Clarke's spheroid, vicinity of Baltimore, near the capes of the Chesapeake Bay, Elizabeth and James Rivers, Va.; also in North Carolina, Pennsylvania, and New Jersey.

G. F. Bird, Aid, Coast and Geodetic Survey, computed secondary geographical positions on Clarke's spheroid in localities Upper Potomac and Blue Ridge, and Savannah River; also some in North Carolina.

J. B. Boutelle computed apparent star places of stars for latitude of Hunter, Mo., 1880; also the astronomical latitude of Hunter.

W. C. Ames attended to the clerical duties of the computing division.

C. B. Turnbull attended to miscellaneous copying, chiefly of descriptions of stations.

C. W. Henderson relieved Mr. Borden from clerical duties, attended to copying geographical positions and to miscellaneous writing.

Yours respectfully,

CHAS. A. SCHOTT,
*Assistant Coast and Geodetic Survey, in charge Computing Division.*

J. E. HILGARD,
*Assistant Coast and Geodetic Survey, in charge of Office and Topography.*

## *ANNUAL REPORT ON THE FIELD AND OFFICE WORK RELATING TO THE TIDES, FOR THE FISCAL YEAR ENDING JUNE* 30, 1881.

I respectfully submit this report on the work of the Tidal Division, of which I have been in charge during the year.

*Observations.*—Self-registering tide-gauges have been used at the following stations:—North Haven, Me.; Providence, R. I.; Sandy Hook, N. J.; Saucelito, Cal.; Kadiak, Alaska; Mazatlan Mexico; and Honolulu, Sandwich Islands. Beside these a self-registering gauge has been loaned to the United States Engineers to be used at Fort Sumter, S. C., and one has been constructed after my plans and under my supervision for the Mississippi River Commission; and intended for use on Lake Borgne, La. Something has been done also toward the construction of an automatic tide-gauge on a new plan, for the purpose of making gauges of this form more generally useful. A gauge has been fitted for use at some point in the Aleutian Islands, but the place has not yet been selected, for want of means. Nothing has been done yet toward securing tidal observations at Bermuda, nor toward resuming and completing the system of observation in the Gulf of Mexico, that was stopped in 1861, nor have permanent observations been resumed on the southern coast.

As quite full information has been given in the tidal notices, under the different sections of the Survey, of the observations made with self-registering gauges during the year, it will not be necessary to add much here, except to state that I would strongly recommend the extensions above indicated as soon as circumstances permit, as they seem to be essential to a complete investigation of the tides on the coast of the United States.

In the following table I give a list of the observations made with self-registering gauges received during the year:

| Section. | Name of station. | Name of observer. | Kind of gauge. | Permanent or temporary. | Time of occupation. | | Total days. |
|---|---|---|---|---|---|---|---|
| | | | | | From— | To— | |
| I. | North Haven, Me | J. G. Spaulding | Self-registering | Permanent | Apl. 25, 1880 | Apl. 26, 1881 | 366 |
| I. | Providence, R. I | Not received | do | Temporary | | | |
| II. | Sandy Hook, N. J | J. W. Bawford | do | Permanent | June 1, 1880 | June 1, 1881 | 365 |
| X. | Saucelito, Cal. | E. Gray | do | do | June 1, 1880 | June 1, 1881 | 365 |
| XII. | Kadiak, Alaska | W. J. Fisher | do | do | Aug. 1, 1880 | Mar. 1, 1881 | 213 |
| | Mazatlan, Mex | Fiacro Quyano | do | do | May 1, 1880 | May 31, 1881 | 395 |
| | Honolulu, S. I | J. S. Emerson | do | Temporary | Feb. 18, 1880 | Dec. 3, 1880 | 288 |

Self-registering tide-gauges have been but little used in the ordinary work of hydrographic parties, partly, no doubt, because gauges of this form were not well adapted for such purposes, and partly on account of their expense, though it can hardly be questioned that much better work would be done with them in places where they can be conveniently established. At present, owing, it seems, to the tediousness of making continuous observations with staff or box gauges, such parties often content themselves with observing tides only during the hours while soundings are being taken. With such imperfect tidal data the reduction of the soundings must be liable to some uncertainty, especially where there is large diurnal inequality or single-day tides. It seems reasonable to expect that some remedy will be found for this. All tidal observations made by hydrographic parties are inspected by me when received at the office, and most of them are reduced by the tidal division. Notices of them will be found in the statements of work done in the different sections of the Survey.

There are four gauges now in the office, three of which need some repairs and new driving clocks to fit them for efficient working.

*Office work.*—Most of the tabulating of high and low waters and hourly ordinates is now done from the curves by the observers before sending the records to the office, and the tabular reductions are sent by separate mail. The risk of loss is thus guarded against, and the observers become more expert and skillful.

The reduction of these observations and of those sent in from the hydrographic parties is attended to as soon as practicable, and the results used in making tide tables for charts and predictions. The division is thus enabled to furnish a large amount of information relating to tides to officers of the Survey, United States Engineers, and others, and the demand for it is continually increasing.

"Tide tables" containing the predictions for the Atlantic and Pacific coasts of the United States for 1882 have been computed by the Tidal Division, and have been published.

The computers employed in this division in the course of the year were R. S. Avery, L. P. Shidy, T. Craig, M. Thomas, and C. B. Turnbull in the office, and J. Downes and J. G. Spaulding out of it.

Mr. Avery, being in charge of the division, inspected all tidal observations when received and prepared them for reduction, attended to the correspondence with observers and others on tides, planned and supervised the work on tides and tide-gauges, prepared copy and read proofs, and computed when not otherwise engaged.

Mr. Shidy reduced many observations received from hydrographic parties, predicted for places where the diurnal inequality is large, and aided in a considerable amount of miscellaneous work.

Dr. Craig continued investigations relating to motion in fluids, the form of fluid rotating bodies, the figure of the earth, the properties of functions, harmonics, &c., discovering some new properties and applications.

Miss Thomas worked partly on tidal reductions, but mostly on hourly ordinates for permanent stations, and aided in miscellaneous work and copying.

Miss Turnbull was employed in tabulating from the tidal curves, and in copying and tracing, till the 22d of January, 1881, when she was transferred to the Computing Division.

Mr. Downes was engaged by contract to make the predictions for certain specified places.

Mr. Spaulding computed the predictions for Boston, as he has generally done, in addition to his services as a tidal observer.

Yours, respectfully,

R. S. AVERY.

Prof. J. E. HILGARD,
*Assistant Coast and Geodetic Survey, in charge of Office and Topography.*

## *REPORT OF THE DRAWING DIVISION, COAST AND GEODETIC SURVEY OFFICE, FOR THE YEAR ENDING JUNE 30, 1881.*

*Drawing Division.*—This Division remained under the charge of Mr. W. T. Bright during the year. The following synopsis shows the principal character of work performed by each person connected with the Division.

A summary of the maps and charts commenced, completed, or in progress within the year will be found in Appendix No. 4, and in Appendix No. 3 is a statement of the information furnished in reply to special calls.

Mr. A. Lindenkohl, a draughtsman of long experience, is constantly called upon for elaborate compilations to illustrate the various scientific papers intended for the annual reports. He has also been employed in keeping up to date the numerous finished maps and charts by adjusting the more recent surveys with the older material and in drawing new charts as the surveys became available. He has, with a great deal of care, compiled in one sheet a new edition of the Gulf of Mexico Sailing Chart, constructed several new progress sketches, and assisted in making a model of the Gulf of Mexico from recent deep-sea soundings.

Mr. H. Lindenkohl has been engaged upon drawings intended for publication by the quick process of photolithography, and in engraving on stone sketches and diagrams for the illustrations of the annual report. He has also reduced for engraving the yearly material for several coast charts, scale $\frac{1}{80000}$, and constructed field projections.

Mr. L. Karcher has constructed many of the projections called for by the different field parties, made tracings from the original sheets, diagrams, and projects, and been engaged upon miscellaneous work.

Mr. P. Erichsen has made drawings of all the new instruments of precision as well as the improvements upon others that have been in use. These are generally intended for engraving upon stone or wood and are drawn with skill and care.

Mr. E. J. Sommer has continued upon drawings for photolithographing, field projections, tracings, and projects.

Mr. C. Junken continued upon hydrographic reductions, field projections, and applied new longitudes to engraved copper plates. He was detached from the division in May to make a minute topographical survey of the site for the new National Observatory.

Mr. T. J. O'Sullivan has been engaged upon a map of the country between Norfolk and Lynn Haven River, Princess Anne County, Va., for publication by photolithography. He has also made titles for and printed the lettering of plane-table sheets, made smooth tracings, and verified engraved charts.

Messrs. R. E. Peary, A. E. Burton, and E. H. Fowler, after continuing during the year in making and lettering plane-table sheets, were transferred to the division of topography.

Mr. A. B. Graham has continued to make tracings, reductions, transfers of shore-line to field projections and to correct chart-room editions for issue with latest information, and other miscellaneous work.

Mr. J. C. Barr has kept up the clerical work of the division and performed other duty in correcting charts.

Mr. H. Eichholtz has been employed as heretofore in adding corrections and coloring light-houses and buoys upon the numerous charts before issue.

Mr. E. Molkow was engaged until the end of the year in correcting and coloring charts when he was transferred to the division of topography.

Mr. B. Bradbury was assigned to the division in January, 1881, and did miscellaneous work until June, when he was directed to report to Assistant Boyd for field duty.

During the year there were sixty charts in progress of completion, and of this number twenty-two were completed including nine for publication by photolithography.

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## *ANNUAL REPORT OF THE ENGRAVING DIVISION FOR THE YEAR ENDING JUNE* 30, 1881.

UNITED STATES COAST AND GEODETIC SURVEY OFFICE,
*Washington, D. C., July* 9, 1881.

SIR: I respectfully submit the following report of work executed in the Engraving Division during the fiscal year ending June 30, 1881.

I entered upon the duties of Chief of Division December 1, 1880; prior to this date the Division had been in charge of Assistant J. S. Bradford.

The statistics of the year's work are as follows: The plates of nine charts, five Atlantic Coast Pilot charts, fifteen Atlantic Coast Pilot views, and five miscellaneous sketches were completed; nineteen charts were re-issued; thirty-one unfinished chart plates received additions.

The plates of three charts, fourteen Alaska Coast Pilot charts, four Alaska Coast Pilot views, and three progress sketches were commenced.

The printing-plates of one hundred and ten charts, eight Atlantic Coast Pilot charts, and twenty-eight progress sketches received additions and corrections.

Sixteen plates in "alto" and seventeen in "basso" were received from the electrotype division.

Many of the plates that received additions and corrections were in hand four or five times. There was also a large amount of miscellaneous work, such as cleaning plates, erasures on "alto," cutting plates, arranging and drawing titles, notes, and general lettering, and marking instruments, &c.

At the close of the year there were thirty-six chart plates and twenty-seven miscellaneous plates in an unfinished condition.

The regular force of engravers has been employed in the several specialties as follows:

Messrs. J. Enthoffer, H. C. Evans, A. Sengteller, and R. F. Bartle, on topography; Messrs. E. A. Maedel, A. Petersen, J. G. Thompson, W. H. Davis, and F. Courtenay, on lettering; Messrs. T. Wasserbach and A. C. Reubsam, on corrections and additions; Mr. H. M. Knight, on lettering and sanding; Mr. W. Thompson, on topography and sanding; Mr. E. H. Sipe, on miscellaneous work; and Mr. F. W. Benner, on sanding.

The clerical duties of the division were performed by Messrs. J. H. Smoot and C. L. Drinkard until early in January, when Mr. Drinkard was assigned other duties, since then by Mr. Smoot alone. During the short time Mr. Drinkard assisted me he conducted himself as a young gentleman of exceptional character, and it was, therefore, with deep regret that I heard of his illness and sudden death.

I transmit herewith a statement of the plates completed, continued, and commenced during the year, and a list of the printing plates that have received additions and corrections.

Yours, very respectfully,

HERBERT G. OGDEN,
*Assistant in Charge of Engraving Division.*

J. E. HILGARD,
*Assistant, Coast and Geodetic Survey,*
*in charge of Office and Topography.*

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## *ANNUAL REPORT OF THE HYDROGRAPHIC DIVISION FOR THE YEAR ENDING JUNE 30, 1881.*

UNITED STATES COAST AND GEODETIC SURVEY OFFICE.

SIR: I have the honor to submit herewith the annual report of the operations, condition, and progress of thework of the Surveyunder my charge. With two exceptions, the hydrographic operations have been conducted by officers detailed from the Navy. In these two cases this class of work has been progressing in conjunction with the topography under the direction of the civil assistants of the Survey, and the progress is detailed in the reports of chiefs of parties.

*Repairs and equipment of vessels.*—Besides the usual repairs incident to the natural decay of vessels in service, the steamer A. D. Bache has had such extensive repairs as have, it is believed, rendered her a more efficient vessel than when she was first built. Originally constructed of iron, the gradual deterioration, due to the action of the salt water and other causes on the material, made it unsafe for her to remain at sea on the exposed portions of our coast, as required, without some protection. A complete sheathing of wood three inches in thickness has, therefore, been placed upon her, which, being coppered, makes her the strongest kind of a composite vessel, now generally conceded to be the most durable class of ships built, effecting economy by requiring less frequent dockings, and less loss of power due to the accumulations of barnacles, grass, &c., on the bottom, consequently saving in fuel. Besides this, the Bache has been fitted with a steam capstan, saving, it is reported, from one to two hours per day for the actual work of the Survey by allowing the small crew to take the time that was usually spent in getting under way for the necessary preparations for the day's work, meals, &c. Other minor items, such as a donkey boiler for heating purposes and distilling water, have been added, thus providing the crew with pure drinking-water at all times, thereby decreasing sickness and permitting the vessel to remain in the field a much longer space of time.

The steamer Endeavor has been provided with a new boiler and otherwise generally overhauled, and is now in very good condition.

The steamers Blake and Gedney on the Atlantic coast, the Hassler and McArthur on the Pacific coast, and the Barataria, Baton Rouge, and Hitchcock on the Mississippi River, have had more or less repairs.

Steam-launches Sagadahoc, Nos. 4 and 5, have received extensive repairs.

The steamer Baton Rouge was sunk in December last by running onto a mud bank, and being of no further use to the Survey was sold. The details of this disaster are given in the report of C. H. Boyd, Assistant.

These steamers, together with the schooners Brisk, Eagre, Earnest, Research, Scoresby, Quick, and Yukon, all of which have required more or less repairing, are the only vessels that have been in general service.

The barge Beauty, and sloops Kincheloe and Steadfast, have been used as quarters for parties, but have received some repairs to keep them in order.

The steamer Arago was fitted out temporarily to take the party attached to the Endeavor while that vessel was undergoing repairs, and was prepared with only minor items of outfit.

The following vessels have been laid up for want of means to put them in service, viz: Steamer Arago, at League Island, Pa.; steamer Fathomer, at Washington, D. C.; schooner G. M. Bache, at Washington, D. C.; schooner Drift, at Brooklyn, N. Y.; schooner Silliman, at Brooklyn, N. Y.

Besides these, several of the vessels above mentioned as in service were laid up before the end of the year; the steamer Barataria at Natchez, Miss.; steamer Hitchcock, at Baton Rouge, La.; schooner Brisk, at Natchez, Miss.; schooner Research, at Algiers, La.; schooner Quick, at Algiers, La.; schooner Scoresby, at Baltimore, Md.; schooner Yukon, at Oakland, Cal.; sloop Steadfast, at Indian River, Fla.

Of the vessels not in use at present the steamer Fathomer is so thoroughly out of repair, and would require such an amount to fit her out, with no immediate prospect for requiring the services of a vessel of her class, that I believe it to be to the best interests of the service to sell her.

The imperative necessity for extensive surveys in the recently acquired Territory of Alaska, for which a vessel of peculiar construction is required, warrants me in submitting to you the question whether a special appropriation should not be requested from Congress to enable the service to build such a vessel. She should, if allowed, be built in the strongest manner, fully equipped as to sail power, enabling her to make the longest passages under sail, with auxiliary steam-power to allow entering difficult approaches under steam, yet with the least amount of fuel possible. Two steam launches should be supplied her for carrying on the surveys in the most expeditious manner. A vessel best adapted to this service would be about one hundred and thirty feet long, twenty-four feet beam, and twelve feet depth. This matter was fully discussed with Mr. C. P. Patterson, the late Superintendent, and it was his intention to submit estimates for a steamer of this class. The sale of the steamers Baton Rouge and Fathomer (if it is decided to sell her) and schooners Caswell, Fauntleroy, and Catalina would, it is thought, warrant this extension of the service.

*Personnel.*—There have been doing duty in the Survey during the past year an average of about fifty officers and three hundred and fifty men, who have been detailed by the Navy Department for hydrographic work.

On the 11th December, 1880, Commander E. P. Lull, U. S. N., was detached from duty as hydrographic inspector of the Survey, and Lieut. Commander C. M. Chester, U. S. N., was detailed by the Navy Department, at the request of the Superintendent, to take his place. The vacancy in charge of the party on board the steamer A. D. Bache was filled by the transfer of Lieut. E. B. Thomas, U. S. N., from the command of the steamer Endeavor, and this vacancy was filled by the appointment of Lieut. H. B. Mansfield, U. S. N., who was one of the officers of the steamer Hassler on her first cruise to the Pacific. Lieut. S. M. Ackley, having been his full term in charge of a party, was detached from the schooner Eagre, and the command of that vessel given to Lieut. H. G. O. Colby, U. S. N.

A number of changes have taken place among the other naval assistants attached to the Survey.

*Office.*—The usual routine duties of the office have been carried on, in which the hydrographic inspector has been most ably assisted by Lieut. C. T. Hutchins, U. S. N., who, during several months, in the absence of Commander Lull on field duty, was in charge of the office. These duties include the plotting and verification of Aids to Navigation on about three hundred charts, the verification of the same on a large number of proof-sheets; the preparation of Notices to Mariners; furnishing of distances required by different departments of the government and others; the verification and transmittal of naval returns of crews to the Navy Department; the plotting and drawing of hydrographic charts; verification of reduced sheets; making tracing of reduced sheets, &c.

The plotting and preparation of hydrographic sheets has been performed by Mr. E. Willenbucher with his usual skill, and he was ably assisted by Messrs. W. C. Willenbucher and F. C. Donn.

The plotting and drafting of original hydrographic sheets are tabulated as follows:

| Names. | Vols. | Angles. | Soundings. | Miles. | Deep sea soundings. |
|---|---|---|---|---|---|
| E. Willenbucher | 72 | 19, 840 | 163, 491 | 3, 089 | 535 |
| W. C. Willenbucher | 50 | 21, 145 | 74, 780 | 2, 677 | 417 |
| F. C. Down | 39 | 15, 313 | 62, 720 | 1, 510 | ........... |
| Total | 161 | 56, 298 | 300, 991 | 7, 276 | 952 |

In addition, owing to the accumulation of work in the Drawing Division, a number of projections have been prepared by Mr. E. Willenbucher for the use of field parties.

Besides the office-work, Mr. W. C. Willenbucher was on field duty for about three and a half months out of the year, and Mr. F. C. Donn about one month.

Very respectfully submitted,

C. M. CHESTER,
*Hydrographic Inspector.*

Prof. J. E. HILGARD,
*Assistant, United States Coast and Geodetic Survey,*
*in charge of Office and Topography.*

# APPENDIX No. 1.

*Distribution of surveying parties upon the Atlantic, Gulf of Mexico, and Pacific coasts, and interior of the United States, during the year ending June 30, 1881.*

| Section. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION I. | | | | |
| Maine, New Hampshire, Vermont, Massachusetts, and Rhode Island, including coast and seaports, bays and rivers. | No. 1 | Topography | H. G. Ogden, assistant; W. I. Vinal, subassistant. | Topography of Dyer's Neck and Petit Manan Point, coast of Maine. |
| | 2 | Topography | A. W. Longfellow, assistant; Bion Bradbury, extra observer. | Plane-table survey of the shores and upper heads of Frenchman's Bay, Me. |
| | 3 | Hydrography | Lieut. S. M. Ackley, U. S. N., assistant; Lieut. H. T. Monahon, U. S. N.; Master Frank E. Sawyer, U. S. N.; Ensign Warner H. Nostrand, U. S. N. | Hydrography of the Penobscot River, Me., between Hampden and Winterport; of the head waters of the Bagaduce River; of Jordan River; of Skilling River; of a portion of Frenchman's Bay, and of Franklin Bay above and including Sullivan Falls, Me.<br>Examination for location of a buoy in Mill Creek Reach, Penobscot River, Me. |
| | 4 | Tidal observations | J. G. Spaulding | Series of tidal observations continued with self-registering tide gauge and meteorological observations recorded at North Haven, entrance of Penobscot Bay, Me. |
| | 5 | Hydrography | Lieut. H. G. O. Colby, U. S. N., assistant; Lieut. H. T. Monahon, U. S. N.; Master Frank E. Sawyer, U. S. N.; Ensign Warner H. Nostrand, U. S. N. | Complete hydrographic survey of Rockland Harbor, Me., and soundings in Muscle Ridge Channel and Skilling River, Me. |
| | 6 | Triangulation | Prof. E. T. Quimby, acting assistant. | Observations commenced at Mount Washington, N. H., and signals re-erected to be observed on from Gile Hill, Vt. |
| | 7 | Triangulation | Prof. V. G. Barbour, acting assistant. | Observations completed at Stations Herrick and North East Mountain, in Vermont. |
| | 8 | Triangulation | R. D. Cutts, assistant | Primary triangulation in Vermont to connect the survey of Lake Champlain with the triangulation of the coast.<br>Observations completed at Potato Hill and Field's Hill, Vt. |
| | 9 | Hydrography | Lieut. H. G. O. Colby, U. S. N., assistant; Lieut. H. T. Monahon, U. S. N.; Master Frank E. Sawyer, U. S. N.; Ensign Warner H. Nostrand, U. S. N. | Hydrographic development of Pickett's Ledge, entrance to Salem Harbor, Mass. |
| SECTION II. | | | | |
| Connecticut, New York, New Jersey, Pennsylvania, and Delaware, including coast, bays, and rivers. | No. 1 | Topography and hydrography. | J. W. Donn, assistant | Topography and hydrography of the south coast of Long Island, N. Y., including a survey of Cornell's Creek. |
| | 2 | Tidal observations | J. W. Banford | Observations continued with the self-registering tide gauge at Sandy Hook, N. J. |
| | 3 | Special operations | F. H. Gerdes, assistant | Re-marking trigonometrical points on the Hudson River. |
| | 4 | Topography and triangulation. | H. L. Whiting, assistant; W. C. Hodgkins, aid; C. H. Van Orden, aid. | Topography of the shores of the Hudson River in the vicinity of West Point, N. Y., and points determined by triangulation for the plane-table survey. |
| | 5 | Reconnaissance | C. O. Boutelle, assistant; J. B. Boutelle, extra observer. | Reconnaissance continued across the northern part of the State of New York for triangulation between Lake Champlain and Lake Ontario. |

## APPENDIX No. 1—Continued.

| Sections. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION II—Continued. | | | | |
| | No. 6 | Primary triangulation. | R. D. Cutts, assistant | Observations completed at Cheever, Blueberry Hill, and Bigelow Station, N. Y., in scheme of primary triangulation to connect Lake Champlain with the coast triangulation. |
| | 7 | Astronomical | G. W. Dean, assistant; Edwin Smith, assistant; F. H. Parsons, aid. | Astronomical observatory erected for telegraphic longitude purposes at Cape May, N. J. |
| | 8 | Astronomical | G. W. Dean, assistant; Edwin Smith, assistant; C. H. Sinclair, subassistant; F. H. Parsons, aid; Carlisle Terry, jr., aid. | Telegraphic longitudes determined by signals between Washington, D. C., and Cape May, N. J. |
| | 9 | Triangulation and topography. | C. M. Bache, assistant; E. L. Taney, aid. | Triangulation points determined for topography in the vicinity of Cape May, N. J., and plane-table survey continued along that portion of the coast. |
| | 10 | Hydrography | Lieut. E. B. Thomas, U. S. N., assistant; Lieut. J. A. H. Nickels, U. S. N.; Masters Charles J. Badger, F. A. Wilner, and Henry Morrell, U. S. N.; Ensign H. F. Reich, U. S. N. | Hydrography of main ship channel, Delaware Bay, from Ship John Light towards Brandywine Shoal light; of Delaware Bay near mouth of Cohansey Creek. Special surveys for Light-House Board of a shoal near the Fourteen Feet Bank; detailed survey of that bank and of the lower end of Joe Flogger shoal; survey for position of a light near Lewes, Del.; survey of Cape May to and including Brown Shoal. |
| | 11 | Triangulation | S. C. McCorkle, assistant | Triangulation of the Delaware River from New Castle to Delaware City. |
| | 12 | Topography | C. T. Iardella, assistant; J. Hergesheimer, subassistant. | Topography of the Delaware River from Fort Mifflin to Chester, Pa., and of the shores of New Jersey from Woodbury Creek to Raccoon Island. |
| | 13 | Triangulation and topography. | R. M. Bache, assistant | Triangulation of the Delaware River from Chester, Pa., to New Castle, Del.; and from Raccoon Island to Penn's Grove, N. J. Topography from Raccoon Island to Penn's Grove, N. J. |
| | 14 | Hydrography | Lieut. H. B. Mansfield, U. S. N., assistant; Lieut. Hugo Osterhaus, U. S. N.; Ensign William H. Allen, U. S. N.; Ensign W. G. Harmon, U. S. N. | Hydrography of the Delaware River from upper end of Little Tinnicum Island to upper end of Marcus Hook; and from Edgemoor to above New Castle, Del. |
| | 15 | Hydrography | H. L. Marindin, assistant; Ensign C. H. Amsden, U. S. N.; Ensign E. M. Katz, U. S. N. | Hydrography of the Delaware River from near the mouth of the Schuylkill River towards Chester, Pa. |
| | 16 | Special operations | F. H. Gerdes, assistant | Re-marking triangulation stations near Philadelphia, Pa. |
| | 17 | Triangulation | Prof. E. A. Bowser, acting assistant. | Triangulation continued in the northern part of New Jersey. |
| | 18 | Triangulation | Prof. L. M. Haupt, acting assistant. | Five stations occupied and two new stations established in the triangulation of Pennsylvania. |
| SECTION III. | | | | |
| Maryland, Virginia, and West Virginia, including bays, seaports, and rivers. | No. 1 | Coast pilot work | J. S. Bradford, assistant; J. R. Barker. | Examination of inland waters between Montauk Point, Long Island, and Cape Charles, Va., for the preparation of a Coast Directory for small craft, and coast views obtained off Cape Henry, Va. |
| | 2 | Hydrography | Commander E. P. Lull, U. S. N., hydrographic inspector; Lieut. E. M. Hughes, U. S. N.; Ensign C. H. Amsden, U. S. N.; W. C. Willenbucher, hydrographic draughtsman. | Hydrography of inland waters along the coast of Maryland and Delaware, north of Chincoteague Inlet. |
| | 3 | Special hydrography. | Gershom Bradford, assistant; W. C. Willenbucher, hydrographic draughtsman. | Examination of oyster-beds in Chesapeake Bay, and survey of shoals off Chincoteague Inlet, Va. |

## APPENDIX No. 1—Continued.

| Sections. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION III—Continued. | | | | |
| | No. 4 | Triangulation .... | S. C. McCorkle, assistant .......... | Triangulation points determined for a plane-table survey of the District of Columbia. |
| | 5 | Triangulation .... | C. H. Sinclair, subassistant........ | Triangulation of District of Columbia completed, and pier at Fort Myer connected by triangulation with United States Naval Observatory for use in experiments relative to the velocity of light. |
| | 6 | Topography ...... | J. W. Donn, assistant; W. C. Hodgkin, aid. | Topography continued for a detailed survey of the District of Columbia. |
| | 7 | Topography ...... | Charles Junken, F. C. Donn ....... | Topographical survey of a site for the new Naval Observatory, District of Columbia. |
| | 8 | Magnetic observations. | Charles A. Schott, assistant ...... | Magnetic observations at Washington, D. C. |
| | 9 | Gravitation ....... | C. S. Peirce, assistant; E. D. Preston. | Pendulum observations and collateral work continued at the Johns Hopkins University, Baltimore, Md. |
| | 10 | Hypsometry ...... | H. F. Walling..................... | Barometric and other observations commenced at points in Maryland for the compilation of a general hypsometric map. |
| | 11 | Astronomical .... | G. W. Dean, assistant; F. H. Parsons, aid. | Astronomical observatories erected for telegraphic longitudes at Strasburg, Va., and Charlestown W. Va. |
| | 12 | Astronomical ..... | G. W. Dean, assistant; Edwin Smith, assistant; C. H. Sinclair, subassistant; F. H. Parsons and Carlisle Terry, jr., aids. | Telegraphic longitude signals exchanged between Washington, D. C., and astronomical stations at Strasburg, Va., and Charleston, W. Va., with observations for latitude at those stations. |
| | 13 | Magnetic observations. | J. B. Baylor, subassistant ........ | Magnetic declination, dip, and intensity determined, with observations for time and azimuth, at Wheeling, Clarksburg, Parkersburg, Charleston and Alderson, W. Va., Covington and Wytheville, Va.; latitude and longitude observed at the last five stations, and observations partially completed at Marion, Va. |
| | 14 | Triangulation .... | A. T. Mosman, assistant; W. B. Fairfield, extra observer. | Stations in West Virginia occupied for extending westward the triangulation towards the Ohio River. |
| SECTION V.<br>South Carolina and Georgia. | No. 1 | Tidal observations. | Lieut. B. D. Greene, U. S. A ....... | Tidal observations at Charleston, S. C. |
| SECTION VI.<br>East Florida, from Saint Mary's River to Anclote Keys on the west coast, including coast approaches, reefs, keys, seaports and rivers. | No. 1 | Hydrography..... | Commander J. R. Bartlett, U. S. N., assistant; Lieut. Charles C. Cornwell, U. S. N.; Master G. W. Mentz, U. S. N.; Master Henry Morrell, U. S. N.; Ensigns Lucian Flynne, E. L. Reynolds, U. S. N. | Deep-sea soundings, dredgings, and temperatures between George's Bank and Charleston, S. C.; soundings between Jupiter Inlet, Fla., and Currituck Light-House, N. C., extending across to the Bahama Banks, with serial temperatures and dredgings for bottom specimens. |
| | 2 | Triangulation, topography, and hydrography. | W. I. Vinal, subassistant; E. L. Taney, aid. | Triangulation, topography, and hydrography of Indian River and adjacent coast, Eastern Florida. |
| | 3 | Hydrography..... | Lieut. E. B. Thomas, U. S. N., assistant; Lieut. J. A. H. Nickels, U. S. N.; Masters Charles J. Badger and Frank A. Wilner, U. S. N.; Ensign H. F. Reich, U. S. N. | Lines of soundings run off Cape Canaveral Shoals and south of Cape Canaveral, east coast of Florida. |
| SECTION VII.<br>Gulf coast and sounds of West Florida, including ports and rivers. | No. 1 | Hydrography... | Lieut. E. B. Thomas, U. S. N., assistant; Lieut. J. A. H. Nickels, U. S. N.; Masters Charles J. Badger, F. A. Wilner, and Ensign H. F. Reich, U. S. N. | Lines of soundings run off Egmont Key, entrance to Tampa Bay, and off Light-House Point, east end of Saint George's Sound, west coast of Florida. |

## APPENDIX No. 1—Continued.

| Sections. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION VIII.<br>Alabama, Mississippi, Louisiana, and Arkansas, including Gulf coast, ports, and rivers. | No. 1 | Hydrography | Lieut. Uriel Sebree, U. S. N., assistant; Lieut. E. M. Hughes, U. S. N.; Ensigns J. W. Stewart, J. C. Colwell, M. L. Wood, and W. B. Caperton, U. S. N. | Hydrography of the Mississippi River, from a point four miles below Donaldsonville, La., to Plaquemine. |
| | 2 | Tidal observations | B. M. Harrod, State engineer of Louisiana. | Tides recorded at Lake Borgne, La. |
| | 3 | Triangulation | C. H. Van Orden, aid; W. B. Fairfield, extra observer. | Triangulation of the Mississippi River completed between Bayou Sara and Baton Rouge, La. |
| | 4 | Triangulation | W. H. Dennis, assistant; J. B. Boutelle, extra observer. | Triangulation of the Mississippi River from Providence, La., connected at Walnut Point with scheme extended from Greenville, Miss. |
| | 5 | Leveling | Andrew Braid, assistant; Isaac Winston, aid. | Lines of precise levels run from Pointe Coupée, La., to Rodney, Miss. |
| | 6 | Triangulation | Charles Hosmer, assistant; J. Hergesheimer, subassistant. | Triangulation of the Mississippi River completed between Vicksburg, Miss., and Lake Providence, La., and between Greenville, Miss., and Walnut Point, Miss. |
| | 7 | Leveling | O. H. Tittmann, assistant; J. B. Weir, subassistant. | Lines of precise levels run from Greenville, Miss., to Glenora, Miss., along the Mississippi River. |
| | 8 | Leveling | J. B. Weir, subassistant; Thomas P. Borden, aid. | Levels of precision carried along the Mississippi River from Glenora, Miss., to Rodney, Miss. |
| | 9 | Triangulation | C. H. Boyd, assistant; Carlisle Terry, jr., and G. F. Bird, aids. | Base line measured at Greenville, Miss., and triangulation commenced. |
| | 10 | Astronomical | Edwin Smith, assistant; Carlisle Terry, jr., aid. | Determination of azimuth of the base line at Greenville, Miss. |
| SECTION IX.<br>Texas and Indian Territory, including Gulf coast, bays, and rivers. | No. 1 | Topography | R. E. Halter, assistant | Topography of the Laguna Madre near Corpus Christi, Tex. |
| | 2 | Hydrography | Lieut. Uriel Sebree, U. S. N., assistant; Lieut. E. M. Hughes, U. S. N.; Ensigns J. W. Stewart, J. C. Colwell, M. L. Wood, and W. B. Caperton, U. S. N. | Hydrography of coast of Texas off Padre Island. |
| SECTION X.<br>California, including the coast, bays, harbors, and rivers. | No. 1 | Magnetic observations. | Lieut. H. E. Nichols, U. S. N., assistant; Lieut. T. D. Bolles, U. S. N.; Lieut. W. T. Swinburne, U. S. N.; Master C. F. Putnam, U. S. N.; Ensigns F. W. Coffin, W. D. Rose, and C. F. Bond, U. S. N. | Magnetic declination, dip, and intensity determined at stations on the coasts of Lower California, Mexico, and Central America, and reconnaissances of Guadalupe Island. |
| | 2 | Tidal observations | Fiacro Quijano, civil engineer | Observations with self-registering tide gauge and meteorological observations at Mazatlan, western coast of Mexico. |
| | 3 | Hydrography | Lieut. E. H. C. Leutze, U. S. N.; Lieuts. E. K. Moore and L. C. Heilner, U. S. N.; Masters W. P. Heilner and R. H. Galt, U. S. N. | Hydrography of the coast completed between Point Arguello and Point Sal, Cal. |
| | 4 | Topography | W. E. Greenwell, assistant | Topography of the coast in vicinity of San Luis Obispo, Cal. |
| | 5 | Tidal observations | E. Gray | Observations continued with self-registering tide gauge at Saucelito, inside of San Francisco Bay, Cal. |
| | 6 | Triangulation | A. F. Rodgers, assistant; D. B. Wainwright, subassistant; J. F. Pratt, subassistant. | Sanhedrin and Cahto stations occupied in scheme of primary triangulation north of San Francisco Bay, Cal. |
| | 7 | Primary triangulation | George Davidson, assistant; B. A. Colonna, assistant; J. S. Lawson, assistant; J. J. Gilbert, assistant; E. T. Dickins, subassistant. | Geodetic operations, including latitude, azimuth, and magnetic observations at stations in the Sierra Nevada range, for the transcontinental triangulation, and site prepared for a primary base line at Yolo, Cal. |

## APPENDIX No. 1—Continued.

| Sections. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION X—Continued. | | | | |
| | 8 | Triangulation and topography. | L. A. Sengteller, assistant; Fremont Morse, aid. | Triangulation and topography of the California coast from Walalla River to Point Arena, Cal. |
| | 9 | Tidal observations | W. D. Alexander | Observations of tides continued with self-registering tide-gauge at Honolulu, Sandwich Islands. |
| SECTION XI. | | | | |
| Oregon and Washington Territory, including coast, interior bays, ports, and rivers. | No. 1 | Topography | Cleveland Rockwell, assistant | Detailed topographical survey of the Columbia River continued from Columbia City; hydrography commenced and triangulation extended in that vicinity to above Saint Helen's, Oreg. |
| | 2 | Topography | E. Hergesheimer | Special topography of the Columbia River, including the Dalles, for Topographical Manual. |
| | 3 | Triangulation and topography. | Eugene Ellicott, assistant | Topography of Port Orchard, W. T., and adjacent shores and inlets of Puget Sound, and triangulation extended to furnish necessary points. |
| | 4 | Hydrography | Lieut. Perry Garst, U. S. N., assistant; Ensigns S. J. Brown and H. T. Mayo, U. S. N. | Hydrography of Port Discovery and adjacent waters, Straits of Juan de Fuca, W. T. |
| | 5 | Reconnaissance | Stehman Forney, assistant; P. A. Welker, aid. | Reconnaissance for a primary base-line site on the shore of Boundary Bay, British Columbia. |
| SECTION XII. | | | | |
| Alaska Territory, including the coast and the Aleutian Islands. | No. 1 | Tidal observations | William J. Fisher | Tidal observations continued with self-registering tide-gauge at Saint Paul's, Kadiak Island, Alaska. |
| | 2 | Special operations. | W. H. Dall, assistant; Marcus Baker. | Astronomical, magnetic, meteorological, current and sea-water temperature observations, with soundings, at stations between Sitka and Chilkaht, coast of Alaska. Collection of notes for Coast Pilot of Alaska. |
| SECTION XIII. | | | | |
| Kentucky and Tennessee | No. 1 | Astronomical observations. | Edwin Smith, assistant; Carlisle Terry, jr., aid. | Determination of azimuth at the base line near Louisville, Ky. |
| | 2 | Geodetic | Carl Schenk, acting assistant | Reconnaissance for scheme of primary triangution to connect the Louisville base and Salt River with the line Riley to Mountain Top in Northern Kentucky. |
| | 3 | Geodetic | Prof. A. H. Buchanan, acting assistant. | Observations completed at four stations, signals erected and one station reoccupied in scheme of primary triangulation in Tennessee. |
| SECTION XIV. | | | | |
| Ohio, Indiana, Illinois, Wisconsin, and Michigan. | No. 1 | Geodetic | Prof. R. S. Devol, acting assistant. | Reconnaissance for the extension of the primary triangulation in Ohio. |
| | 2 | Astronomical | G. W. Dean, assistant; F. H. Parsons, aid. | Astronomical observatory erected for telegraphic longitude observations at Cincinnati, Ohio. |
| | 3 | Magnetic observations. | J. B. Baylor, subassistant | Magnetic declination, dip, and intensity determined at Cleveland, Ohio, Grand Haven, Mackinac, Sault Ste. Marie, and Ontonagon, Mich., Superior City, Wis., Vincennes, New Harmony, Indianapolis, and Richmond, Ind., Cincinnati and Athens, Ohio, with observations for approximate geographical positions of stations occupied. |
| | 4 | Geodetic | Prof. J. L. Campbell, acting assistant. | Reconnaissance for the scheme of primary triangulation in Indiana. |
| | 5 | Primary triangulation and reconnaissance. | G. A. Fairfield, assistant; F. W. Perkins, assistant; Isaac Winston, aid. | Continuation of, and reconnaissance for, primary triangulation eastward along the Thirty-ninth Parallel in Illinois. |
| | 6 | Geodetic | Prof. J. E. Davies, acting assistant. | Four stations occupied and observations made for latitude and azimuth at two stations on the triangulation of Wisconsin. |
| | 7 | Magnetic observations. | Prof. J. E. Davies, acting assistant; G. W. Suess. | Observations of magnetics continued at the permanent Magnetic Observatory, Madison, Wis. |

## APPENDIX No. 1—Continued.

| Sections. | Parties. | Operations. | Persons conducting operations. | Localities of work. |
|---|---|---|---|---|
| SECTION XV. | | | | |
| Missouri, Kansas, Iowa, Nebraska, Minnesota, and Dakota. | No. 1 | Triangulation .... | F. D. Granger, assistant; H. W. Blair, subassistant; Carlisle Terry, jr., aid; Thomas P. Borden, aid. | Primary triangulation extended westward in Missouri from stations Hunter and North Base. |
| | 2 | Magnetic observations. | J. B. Baylor, subassistant .......... | Magnetic elements determined at Brainerd and Glyndon, Minn., Pembina, Jamestown, and Bismarck, Dak., Fort Snelling and Heron Lake, Minn., Yankton, Dak., Omaha, Nebr., and Dubuque, Iowa, with observations for approximate geographical positions of stations occupied. |
| SECTION XVI. | | | | |
| Nevada, Utah, Colorado, Arizona, and New Mexico. | No. 1 | Primary triangulation and magnetic observations. | William Eimbeck, assistant; R. A. Marr, aid. | Primary triangulation in Nevada continued eastward along the Thirty-ninth Parallel, and magnetic elements determined at stations in Nevada and Utah Territory. |
| | 2 | Primary triangulation. | O. H. Tittman, assistant; J. E. McGrath, aid; G. F. Bird, aid. | Primary triangulation in Colorado extended eastward from the El Paso base. |

# APPENDIX No. 2.

*Statistics of field and office work of the United States Coast and Geodetic Survey for the year ending December* 31, 1880.

| Description. | Total to December 31, 1879. | 1880. | Total to December 31, 1880. |
|---|---|---|---|
| RECONNAISSANCE. | | | |
| Area in square statute miles | 269, 950 | 5, 440 | 275, 390 |
| Parties, number of, in year | ............ | 4 | ............ |
| BASE LINES. | | | |
| Primary, number of | 13 | 0 | 13 |
| Subsidiary, number of | 116 | 5 | 121 |
| Primary, length of, in statute miles | 79 | 0 | 79 |
| Subsidiary, length of, in statute miles | 265¾ | 5¼ | 271 |
| TRIANGULATION. | | | |
| Area in square statute miles | 138, 393 | 15, 490 | 153, 883 |
| Stations occupied for horizontal angles, number of | 9, 555 | 399 | 9, 954 |
| Geographical positions determined, number of | 17, 819 | 870 | 18, 689 |
| Stations occupied for vertical angles, number of | 561 | 39 | 600 |
| Elevations determined, number of | 1, 483 | 104 | 1, 587 |
| Lines of spirit leveling, length of | 1, 356 | 480 | 1, 836 |
| Parties, triangulation and leveling, number of, in year | ............ | 35 | ............ |
| ASTRONOMICAL WORK. | | | |
| Azimuth stations, number of | 154 | 14 | 168 |
| Latitude stations, number of | 261 | 12 | 273 |
| Longitude stations (telegraphic), number of | 101 | 1 | 102 |
| Longitude stations (chronometric and lunar), number of | 110 | 0 | 110 |
| Astronomical parties, number of, in year | ............ | 8 | ............ |
| MAGNETIC WORK. | | | |
| Stations occupied, number of | 440 | 96 | 536 |
| Permanent magnetic stations, number of, in year | ............ | 1 | ............ |
| Magnetic parties, number of, in year | ............ | 6 | ............ |
| TOPOGRAPHY. | | | |
| Area surveyed in square miles | 27, 099 | 701 | 27, 800 |
| Length of general coast, in miles | 6, 099 | 91 | 6, 190 |
| Length of shore line, in miles (including rivers, creeks, and ponds) | 76, 160 | 2, 466 | 78, 626 |
| Length of roads, in miles | 39, 628 | 867 | 40, 495 |
| Topographical parties, number of, in year | ............ | 19 | ............ |
| HYDROGRAPHY. | | | |
| Parties, number of, in year | ............ | 11 | ............ |
| Number of miles run while sounding | 329, 634 | 6, 399½ | 336, 033½ |
| Area sounded, in square miles | 79, 199 | 3, 209 | 82, 408 |
| Miles run, additional of outside or deep-sea soundings | 66, 066 | 5, 093 | 71, 159 |
| Number of soundings | 15, 182, 326 | 239, 888 | 15, 422, 214 |
| Deep-sea soundings, number of, in year | ............ | 535 | ............ |
| Deep-sea temperature observations, number of, in year | ............ | 1, 342 | ............ |
| Tidal stations, permanent | 241 | 7 | 248 |
| Tidal stations occupied temporarily | 1, 751 | 27 | 1, 778 |
| Tidal parties, number of, in year | ............ | 22 | ............ |
| Current stations, occupied | 518 | 41 | 559 |
| Current parties, number of, in year | ............ | 2 | ............ |
| Specimens of bottom, number of | 11, 102 | 178 | 11, 208 |
| RECORDS. | | | |
| Triangulation, originals, number of volumes | 2, 808 | 441 | 3, 249 |
| Astronomical observations, originals, number of volumes | 1, 397 | 90 | 1, 487 |
| Magnetic observations, originals, number of volumes | 464 | 21 | 485 |
| Duplicates of the above, number of volumes | 2, 967 | 383 | 3, 350 |
| Computations, number of volumes | 2, 953 | 203 | 3, 156 |

## APPENDIX No. 2—Continued.

| Description. | Total to December 31, 1879. | 1880. | Total to December 31, 1880. |
|---|---|---|---|
| RECORDS—Continued. | | | |
| Hydrographical soundings and angles, originals, number of volumes | 7, 890 | 224 | 8, 114 |
| Hydrographical soundings and angles, duplicates, number of volumes | 1, 204 | 95 | 1, 299 |
| Tidal and current observations, originals, number of volumes | 3, 254 | 59 | 3, 313 |
| Tidal and current observations, duplicates, number of volumes | 2, 115 | 20 | 2, 135 |
| Sheets from self-registering tide-gauges, number of | 2, 697 | 66 | 2, 763 |
| Tidal reductions, number of volumes | 1, 758 | 34 | 1, 792 |
| Total number of volumes of records* | 26, 810 | 1, 570 | 28, 380 |
| MAPS AND CHARTS. | | | |
| Topographical maps, originals | 1, 578 | 29 | 1, 607 |
| Hydrographic charts, originals | 1, 566 | 56 | 1, 622 |
| Reductions from original sheets | 868 | 25 | 893 |
| Total number of manuscript maps and charts to and including 1880 | 2, 629 | 25 | 2, 654 |
| Number of sketches made in field and office | 3, 074 | 36 | 3, 110 |
| ENGRAVING AND PRINTING. | | | |
| Engraved plates of finished charts, number of | 227 | 13 | 240 |
| Engraved plates of preliminary charts, sketches, and diagrams for the Coast and Geodetic Survey Reports, number of | 590 | 19 | 609 |
| Electrotype plates made | 1, 454 | 66 | 1, 520 |
| Finished charts published (including reissues) | 294 | 26 | 320 |
| Preliminary charts and hydrographical sketches published | 504 | 17 | 521 |
| Engraved plates of Coast Pilot charts | 41 | 17 | 58 |
| Engraved plates of Coast Pilot views | 53 | 18 | 71 |
| Printed sheets of maps and charts distributed | 431, 211 | 27, 848 | 459, 059 |
| Printed sheets of maps and charts deposited with sale agents | 159, 044 | 14, 783 | 173, 827 |
| LIBRARY. | | | |
| Number of volumes | 6, 911 | 188 | 7, 099 |

* These totals include all under head of records, except "Sheets from self-registering tide-gauges."

# APPENDIX No. 3.

*Information furnished from the Coast and Geodetic Survey Office by tracings from original sheets, transcripts of records, &c., in reply to special calls during the year ending June* 30, 1881.

| Date. | | Name. | Data furnished. |
|---|---|---|---|
| 1880. | | | |
| July | 2 | Maj. F. U. Farquhar, U. S. A., engineer-secretary Light-House Board. | Information relative to mean low-water line in vicinity of Front Beacon, Cherry Island Flats. |
| | 3 | Samuel McElroy & Son, civil engineers, 336 Fulton street, Brooklyn, N. Y. | Topographical survey, of 1835, of the south shore of Long Island, Far Rockaway to South Oyster Bay. |
| | 8 | T. B. Ferguson, Assistant United States Fish Commissioner | Topographical survey of the western shore of Chesapeake Bay, vicinity of Saint Jerome's Creek, Maryland. |
| | 8 | United States Fish Commissioners | Small map of the District of Columbia, with horizontal curves emphasized. |
| | 19 | Capt. J. C. P. de Kraft, hydrographer, U. S. N. | Position of astronomical station on Hazen's Bay, Atoka Island, Aleutian Group. |
| | 23 | James H. Wilson, vice-president New York and New England Railroad Company. | Hydrographic survey of the Hudson River from New Windsor to Sherman's dock, including Newburg. |
| | 26 | Thomas Bernard, city engineer, Norfolk, Va | Topographical survey of part of Princess Anne County, Va., northeast of Norfolk, from water works to Bradford's pond. |
| | 30 | Col. W. P. Craighill, United States Corps of Engineers | Topographical survey of Greensbury's Point, and shore-line of Annapolis, Md., and hydrographic survey of Onancock Creek, Accomac County, Va., 1869. |
| Aug. | 4 | Prof. S. J. Coffin, Lafayette College, Easton, Pa | Copy of papers on secular change of magnetic declination and notes on measurement of terrestrial magnetism. |
| | 9 | Prof. H. M. Paul, University of Tokio, Japan | Difference of telegraphic longitude Nagasaki and Tokio. |
| | 9 | John Markoe, 319 Walnut street, Philadelphia | Topographical survey of the east side of Mount Desert Island, Me., vicinity of Bear Brook. |
| | 9 | E. P. Cole, South Deer Isle, Me | Unfinished proof of Isle au Haut Bay and Eggemoggin Reach, Me. |
| | 9 | General Schuyler Hamilton, Jamaica, Long Island, N. Y. | Hydrographic survey of Cornell's or Mill Creek, Jamaica Bay, Long Island. |
| | 11 | J. P. Storey | Copy of tidal bench-marks at Charleston, S. C. |
| | 12 | Verplanck Colvin, superintendent Adirondack Survey, New York. | Latitude, longitude, and azimuth, and distances of three principal geodetic stations in New York and Vermont. |
| | 17 | John S. Tucker, clerk to joint committee of Congress on Yorktown monument. | Topographical survey of Yorktown, Va., made in 1857. |
| | 17 | E. P. Cole, South Deer Isle, Me | Unfinished proofs brought up by hand of topography of Blue Hill and Frenchman's Bays, including the island of Mount Desert, Me., scale 1-40,000. |
| | 18 | Prof. R. B. Fulton, University of Mississippi, Oxford, Miss. | Constants for their magnetic instruments and pamphlet on magnetic measurements. |
| | 20 | General John Newton, United States Corps of Engineers | Hydrographic survey of Cornell's or Mill Creek, Jamaica Bay, L. I.<br>Hydrographic survey of Patchogue Creek, Long Island, N. Y.<br>Hydrographic survey of Sumpwams or Babylon Creek, Long Island, N. Y. |
| | 24 | General Q. A. Gillmore, United States Corps of Engineers. | Copies of sketches showing location of permanent bench-marks along the Mississippi River, on line of geodetic levels between Greenwell and Vicksburg, 1880. |
| | 25 | General Newton, United States Engineers | Copy of tidal bench-marks at Patchogue, Great South Bay, Long Island, also bench-marks near Holland House, Jamaica Bay, Long Island. |
| | 27 | General Thom, United States Engineers | Information relative to the tidal bench-mark at the mouth of the river near Newburyport. |
| | 27 | Sanderson Smith, United States Fish Commission | Proofs of general coast chart No. I, Isle au Haut, Me., to Cape Cod, with 60 and 70 fathom curves drawn by hand, and proof of general coast chart No. II, Cape Ann to Gay Head, with curves of 30, 60, 75, and 100 fathoms drawn by hand. |
| | 28 | Julius Bien, New York | General coast chart No. 675, Point Pinos to Bodega Head, California, and unfinished proof of Santa Barbara channel, California, scale 1-200,000, with additions of coast-line by hand. |

## APPENDIX No. 3—Continued.

| Date. | | Name. | Data furnished. |
|---|---|---|---|
| 1880. | | | |
| Sept. | 4 | R. D. Mussey, Washington, D. C | Received height of Clark Mountain, Virginia. |
| | 6 | J. P. Bradley, Associate Justice United States Supreme Court. | Geographical position of Mount Marshall, Vermont. |
| | 7 | Capt. Stephen B. Luce, U. S. N., commanding United States training-ship Minnesota. | Preliminary plotting of hydrographic survey of anchorage in Coasters Island Harbor, Rhode Island. |
| | 8 | Lieut. Col. N. Michler, United States Corps of Engineers | Topographical survey of Mattawan or Middletown Creek, Raritan Bay, N. J., with hydrography off its mouth. |
| | 9 | G. Daubeney, United States assistant engineer | Description of tidal bench-marks at Absecon Inlet, N. J. |
| | 10 | Lieutenant Hoxie, United States engineer | Data relating to tides in the Potomac at and above Washington. |
| | 10 | Mr. Campbell Carrington | Predictions for one day's tides in the Patuxent. |
| | 10 | J. S. Copes, president New Orleans Academy of Science | Latitude and longitude of astronomical station of 1880 at New Orleans. |
| | 11 | B. W. Maples, editor of the Norwalk Hour | Directions for forming tide-tables for his paper. |
| | 14 | J. P. Little, Belzoni, Washington County, Miss | Information on secular change of magnetic declination since 1827-'28, and 1880, and on annual change for these epochs. |
| | 22 | General John Newton, United States Corps of Engineers | Hydrographic survey of Jamaica Bay, Long Island, N. Y., in vicinity of Cornell's or Mill Creek. |
| | 24 | Lieut. Col. F. O. Wyse, Pikesville, Baltimore County, Md | Pamphlet on magnetic secular change. |
| | 25 | H. A. Bentley, assistant engineer with General Newton at Newport, R. I. | Information relating to tidal observations at Providence. |
| | 27 | George E. Waring, jr., expert and special agent Tenth Census. | Topographical survey of the Hackensack River Valley, from Hudson City to Hackensack, and English Creek to Leonia, N. J.; surveyed between 1871 and 1874. |
| | 27 | James S. Yard, Freehold, N. J | Heights of trigonometrical stations and of bench-marks in Monmouth County and vicinity. |
| | 27 | Lieut. L. A. Chamberlain, U. S. A | Position and description of station, Yorktown, Va., and of five adjacent trigonometrical stations. |
| Oct. | 11 | Cross, Bergen & Nae, counsellors at law, Elizabeth, N. J | List of geographical positions of lights near Elizabeth. |
| | 14 | General John Newton, United States Engineers | Geographical positions harbor New York, and near Throgg's Neck. |
| | 14 | Maj. G. L. Gillespie, United States Engineers | Hydrographic survey of main channel Columbia River, Oreg., vicinity of Walker's Island; also copy of topographical survey of Martin's Island to Columbia River. |
| | 14 | A. M. Clayton, Mississippi | Topographical survey mouth of Pearl River to railroad bridge, Mississippi and Louisiana. |
| | 16 | O. W. Gray & Son, Philadelphia | A table of telegraphic longitude results for stations in and near Kansas. |
| | 16 | Commandant Perrier, Paris | Table of statistics of principal base-lines measured in the Coast and Geodetic Survey between 1834 and 1837. |
| | 18 | General John Newton, United States Corps of Engineers | Topographical survey of islands in Long Island Sound in vicinity New Rochelle Harbor, 1837 and 1850. |
| | 18 | General Q. A. Gillmore, United States Corps of Engineers | Unfinished proof coast chart No. 58, Cumberland Sound to Saint John's River, Fla., scale 1-80,000; brought up by hand. |
| | 19 | Light-house supply steamer Fern | Unfinished proof general coast chart No. VIII, Cumberland Sound to Cape Canaveral, Fla., scale 1-400,000; brought up by hand; also unfinished proof coast chart No. 95, Mississippi River forts to New Orleans, scale 1-80,000; brought up by hand. |
| | 19 | E. S. Kemper, surveyor-general, Rockingham County, Va | Two magnetic pamphlets and magnetic declination observed at Harrisonburg, Va. |
| | 21 | W. Senter, mayor of Portland, Me | List of geographical positions in vicinity of Portland, Me. |
| | 26 | Col. John M. Macomb, United States Corps of Engineers | Topographical survey, scale 1-20,000, of the survey of Little Creek, Delaware River, 1842. |
| | 27 | W. H. Hall, State Engineer of California, Sacramento, Cal | List of geographical positions and correction to published positions in the annual reports. |
| | 27 | William H. Nicholson, topographer, Post-Office Department | A series of maps partly engraved, partly traced, and partly reduced for the purpose, comprising the coast of California from the Mexican boundary to 42° latitude, to wit: A, Coronados; B, San Diego Bay; C, from San Diego to Point Vincent; D, Santa Barbara Channel; E, from Point Conception to Point Pinos; F (1), from Point Pinos to Bodega Head; F (2), Suisun Bay; G, From Salmon Creek to Walalla River; H, from Point Arena to Cape Mendocino; I, from Mendocino to Patrick's Pinnacle; K, from Patrick's Pinnacle to Crescent City; L, Crescent City and Saint George's Reef; M, from Lake Earl to Oregon boundary. |
| Nov. | 5 | E. C. Jordan & Co., civil engineers | List of geographical positions of some principal stations in the vicinity of Portland. |

## APPENDIX No. 3—Continued.

| Date. | Name. | Data furnished. |
|---|---|---|
| 1880.<br>Nov. 5 | Henry Willard, Esq | Topography east side Hudson River, Dobbs Ferry to Irvington, including Sunnyside. |
| 5 | Col. John N. Macomb, United States Corps of Engineers | Topography of Broadkill Creek, and hydrography off its mouth, Delaaware Bay, 1842. |
| 5 | Thomas J. Long, assistant engineer, Department of Docks, New York. | Information relating to the kind of float-line used on Coast Survey self-registering tide-gauges. |
| 12 | T. H. Tyndale | Topographical survey of Osterville and vicinity, Barnstable Township, Mass., 1846. |
| 15 | General H. G. Wright, Chief of Engineers | Position of Buenavista, Cal. |
| 18 | George N. Colby & Co., Ellsworth, Me | Coast chart No. 3, Mount Desert Island and vicinity, Me., scale 1-80,000, brought up by hand. |
| 19 | H. G. Schofield, chief engineer, Bridgeport, Conn | Connecticut shore, Stratford to Bridgeport, survey of 1837. |
| 22 | Col. John Newton, United States Corps of Engineers | Hydrography about the islands in Long Island Sound, vicinity New Rochelle Harbor. |
| 23 | United States Light-House Board | Hydrographic survey of Fourteen Feet Bank and southern part of Joe Flogger Shoal, Delaware Bay, 1880. |
| 30 | C. H. Haswell, New York | Information respecting radii of terrestrial spheroid. |
| Dec. 2 | Bureau of Navigation, Navy Department | List of prominent geographical positions on the coast of California. |
| 6 | Mississippi River Commission | Descriptions of bench-marks of line of spirit-levels between Greenville, Miss., and Milliken's Bend, La.; also between Carrollton, La., and Fort Adams, Miss., together with their differences of height. |
| 7 | General C. B Comstock, United States Corps of Engineers. | Copy of triangulation sketch, Mississippi River, north of Vicksburg. |
| 7 | Mississippi River Commission | Table of geographical positions, vicinity and north of Vicksburg, Miss. |
| 10 | J. D. Pool, Captain Engineers, U. S. A | List of geographical positions, Charleston, and magnetic declination for same place for 1881; also, annual change. |
| 14 | Prof. C. A. Young, Princeton, N. J | Geographical position of Princeton. |
| 16 | Mayor Latrobe, Baltimore | Geographical position of Washington Monument, and difference of longitude, Baltimore and Washington. |
| 20 | Samuel Barnett, jr., Washington, Ga | Table of magnetic declinations for Milledgeville, Ga., and Columbia, S. C., from 1800 to 1880. |
| 21 | A. W. Shaffer, Raleigh, N. C | Latitude and longitude of Raleigh; also, with magnetic declination and two magnetic pamphlets. |
| 21 | O. H. Tripp, Blue Hill, Me | Copy of plane-table sheet, vicinity of Blue Hill Bay, Me., showing position of a dwelling, its latitude, longitude, and height above the sea. |
| 27 | O Sprague, Fulton, Whiteside County, Ill | Information as to the change of magnetic declination at that place between 1844 and 1881. |
| 30 | G. B. Strawn, Salem, Ohio | Information respecting a magnetic declination. |
| 1881.<br>Jan. 4 | Mississippi River Commission | Geographical positions in the vicinity of Vicksburg, and some miles above and below that city. |
| 5 | do | Triangulation sketches between Grand Gulf and Vicksburg, and north of Vicksburg, 1879 and 1880. |
| 6 | Prof. C. A. Young | Comparison of astronomical and geodetic difference of longitude, Washington, D. C., and Princeton, N. J. |
| 10 | N. Tyler, No. 55 Oak Street, Baltimore, Md | Twenty-five copies of chart of Delaware and Chesapeake Bays, showing by hand the proposed canal routes called the Sassafras and Choptank. |
| 10 | Hon. William Kimmell | Seventy-five copies chart of Delaware and Chesapeake Bays, showing, by hand, the proposed canal routes. |
| 13 | Mr. Yulee, Florida | Corrections by hand on Saint Mary's River and Fernandina Harbor, chart scale, 1-20,000. |
| 21 | Prof. S. P. Langley, Director of Allegheny (Pa.) Observatory | Scheme of triangulation in California and Nevada, Lola-Round Top to Eureka-White Pine, to November, 1880. |
| 24 | C. H. Burgess, Cleveland, Ohio | Latitude and longitude of Columbus, Ohio, and description of Coast and Geodetic Survey astronomical station at that place. |
| 25 | Th. Wagner, United States Surveyor-General's office, San Francisco, Cal. | List of geographical positions determined in California. |
| 27 | The University of the State of Missouri | Complete sets of charts published by the office and numbered as per catalogue. |
| Feb. 1 | Hon. James T. Farley | Sketch showing graphically the whole number of vessels passing a given point of the coast between San Francisco and the Straits of Fuca, ending August, 1878. |
| 1 | Hon. William A. Wheeler, President of the Senate | Sketch showing graphically the whole number of vessels passing a given point of the coast between San Francisco and the Straits of Fuca, ending August, 1878. |

## APPENDIX No. 3—Continued.

| Date. | Name. | Data furnished. |
|---|---|---|
| 1881.<br>Feb. 3 | Prof. George H. Cook, State Geologist of New Jersey | Description of station Buttermilk. |
| 5 | B. M. Harrod | Height of bench-mark on Hollywood Plantation, East Baton Rouge Parish, above initial bench-mark at Carrollton, La. |
| 7 | William N. Dykman, Brooklyn, N. Y | Topographical survey of Rockaway and vicinity, Long Island, N. Y., 1856–1860. |
| 15 | O. S. Wilson, assistant in charge of State survey | Azimuth of lines from Tassel Station to Barto and Prospect Stations. |
| 16 | Prof. S. Newcomb, Superintendent Nautical Almanac | Information of records of transit of Mercury, May, 1845, at fourteen stations, collected by the Coast Survey; information about the position of Rittenhouse's Transit of Venus Station of 1769 at Philadelphia. |
| 16 | Bureau of Navigation | Proof of part of general chart of the coast No. 671, scale 1–200,000, Newport entrance to Monica Bay, with San Clement and Santa Catalina Islands, Cal. (brought up by hand). |
| 16 | For Department of the Interior; Census Office (Eugene A. Smith), Tuscaloosa, Ala. | Proof of general chart of the coast, scale 1–80,000. From Cumberland Sound, Ga., to Cape Canaveral, Fla., embracing Nos. 58, 59, 60, and 61 (brought up by hand). |
| 16 | ....do | Proof of unfinished chart of the coast, No. 71, scale 1–80,000, Rebecca Shoal to the Tortugas (brought up by hand). |
| 16 | ....do | Proof of unfinished chart of the coast, No. 75, scale 1–80,000, Charlotte Harbor and approaches (brought up by hand). |
| 16 | Bureau of Navigation | Proof of general chart of the coast, No. 672, Monica Bay to Point Conception, including the Channel Islands, Cal., scale 1–200,000 (brought up by hand). |
| 16 | .... do | Proof of general chart of the coast, No. 677, Point Arena to Cape Mendocino, scale 1–200,000 (brought up by hand). |
| 16 | Department of the Interior; Census Office (Eugene A. Smith), Tuscaloosa, Ala. | Proof of unfinished chart of the coast, No. 77, scale 1–80,000, Tampa Bay and approaches (brought up by hand). |
| 16 | ....do | Proofs of unfinished charts of the coast, scale 1–80,000, embracing No. 79, Chassahowitzka River to Cedar Keys; No. 81, Apalachee Bay; No. 82, Apalachee Bay, Apalachicola Bay; No. 83, Apalachicola Bay to Cape San Blas; No. 84, Saint Joseph's and Saint Andrew's Bays; No. 85, Saint Andrew's Bay to Choctawhatchee Inlet; No. 87, Pensacola Entrance to Mobile Bay. |
| 19 | W. C. Kerr, State Geologist North Carolina | List of trigonometrical positions in Northern Georgia and Western South Carolina, and along the southwestern corner of North Carolina; also, table of twenty-three heights of stations in South Carolina and thirty-four in Georgia, near the North Carolina line. |
| 23 | Hydrographic Office, Bureau of Navigation | Information respecting the position of Bear Island. |
| 25 | Maj. G. L. Gillespie, United States Corps of Engineers | Outlines of plane-table sheet of Columbia River from Kalama to Columbia City, scale 1–10,000, 1879; also, unfinished proof of chart No. 4, Columbia River, Grim's Island to Kalama, scale 1–40,000. |
| Mar. 2 | Edward Woodman, Maine | Topographical survey of part of Cape Elizabeth, Me., enlarged from the original 1–10,000 scale maps to a scale of 18 inches to the mile. |
| 7 | A. T. H. Brower, president, East Rome, Town County, Ga. | Magnetic declination at Rome, Ga., and present annual change of same. |
| 7 | J. H. Whitlock, Eufaula, Ala. | Latitude and longitude of astronomical station at Eufaula, and difference of time between Eufaula and Washington. |
| 9 | J. S. Greever, Town House P. O., Smyth County, Va | Pamphlet on secular change, third edition, 1879. |
| 9 | C. C Perkins, City Surveyor's Office, Boston | Description of station Corey's Hill, Mass. |
| 11 | C. Carpmael, Director Toronto Magnetic and Meteorological Observatory. | Analytical representation of the results for magnetic declination observed at Toronto, Canada. |
| 12 | General B. M. Harrold, State Engineer of Louisiana, New Orleans, La. | Letter from Mr. Avery, containing suggestions as to the best way of setting up the new tide-gauge made by Fauth & Co., under Mr. Avery's supervision, and after his drawings. The gauge and float-tube sent. Appendix No. 8, Report of 1876, and Coast Survey Report for 1866, were sent at the same time. The gauge was made for the Mississippi River Commission, to be used at Lake Borgne. |
| 16 | F. J. Simmonds, United States Revenue Marine | Proof of coast chart No. 43, Pamplico Sound, middle sheet, Harbor Island, to Wyesocking Point, N. C. (brought up by hand). |
| 18 | J. Schubert, engineer and architect, Parkersburg, W. Va. | Magnetic declination at Marietta, Wheeling, and Parkersburg. |
| 18 | Persifer Frazier, Philadelphia | Geographical positions and magnetic declination for several places in Virginia. |
| 19 | A. M. Ford, Atlantic City, N. J | Data relating to the formation of tide-tables for Fernandina, Fla. |
| 22 | F. Russell, United States Lake Survey | Information of coefficients of expansion of steel, brass, and zinc bars, and references thereto. |
| 23 | D. B. Hempsted, New London | Longitude of New York City Hall and of three places in New London. |

## APPENDIX No. 3—Continued.

| Date. | Name. | Data furnished. |
|---|---|---|
| March 26 | Thomas Bernard, City Engineer, Norfolk, Va | Tidal observations made during several months at Norfolk, in 1872 and 1873, by the Coast Survey. |
| 30 | James S. Greever, Town House P. O., Smyth County, Va | Table of secular change from 1800 to 1885, computed for the position of Emory and Henry College. |
| 30 | E. R. Trafford, Brooksville, Fla | Proof of unfinished chart of Charlotte Harbor, Fla., scale 1–80,000 (brought up by hand). |
| 30 | C. H. Campbell, New York | Prediction of tides for two days in May (4th and 5th), 1884, for Ashepoo River, S. C., or Helena Sound, the nearest point to it. |
| April 2 | General C. B. Comstock, Chairman Committee on Surveys and Explorations, Detroit, Mich. | Geographical positions and descriptions of astronomical stations Wittenburg and Cape Girardeau, Mo. |
| 5 | Samuel P. Thompson, 56 South Gay Street, Baltimore, Md. | Fifty copies of chart 376, Delaware and Chesapeake Bays, with proposed canal routes known as the Sassafras and Choptank routes (added by hand). |
| 5 | J. P. Cilley, Rockland, Me | Tracing topography of Ensign Islands, &c., with surrounding hydrography of Penobscot Bay. |
| 6 | T. W. Wright, Assistant Engineer United States Lake Survey. | Abstracts of directions stations Fork, Clark, Spear, Humpback, and resulting directions. |
| 11 | General Comstock, Superintendent United States Lake Survey. | Preliminary results of spirit-levelings, Mississippi River, Carrollton, La., to Greenville, Miss. |
| 13 | Prof. John Milne, F. G. S. of the University of Tokio, Japan. | Tracings of curves from the self-registering tide-gauge at Fort Point, Cal., showing the effects of earthquakes in 1868 and 1877. |
| 13 | General Q. A. Gillmore, United States Corps of Engineers, President Mississippi River Commission. | Sketch of the Mississippi River triangulation north from Donaldsonville to Greenwell, scale 1–200,000. |
| 13 | Col. G. K. Warren, United States Corps of Engineers | Hydrographic survey, 1845, of Buzzard's Bay, Mass., from Wing's Neck Light-House to Buttermilk Bay, including hydrography into Monument River as far as surveyed. |
| 22 | J. P. Bogart, Bridgeport, Conn | Geographical positions vicinity of Fairfield, Conn., and descriptions of stations. |
| 22 | P. M. Price, Lieutenant of Engineers, Portland, Oreg | Geographical positions and descriptions of stations mouth of Columbia River. |
| 23 | Capt. C. L. Hooper | Instructions for observing total magnetic intensities by means of the dipping needle |
| 27 | W. A. Duncan, Falls Church, Va | Table of magnetic declinations for Falls Church from 1820 to 1885. |
| 27 | A. B. Cross, Baltimore, Md | Height of trigonometrical station, Mount Rose, N. J. |
| 27 | V. Colvin, Superintendent Survey of the Adirondacks | Angles measured at Blueberry and results for position and length of line Prospect to Blueberry. |
| 28 | General Q. A. Gillmore, United States Corps of Engineers | Unfinished chart Charlotte Harbor, Fla., scale 1–80,000, with additions by hand. |
| 28 | Henry M. Wightman, City Engineer, Boston, Mass | Hydrographic survey of channel between Boston and South Boston, 1847. |
| 30 | R. D. Whitcomb, Assistant Engineer James River Improvements, Richmond, Va. | Plane of reference for mean low water on the Coast Survey tide-staff at Curl's Wharf, James River. |
| 30 | Prof. S. Newcomb | Transcript of records of transit of Mercury, May, 1845, observed in the United States and collected by the Coast Survey. |
| May 4 | E. B. Van Winkle, Department of Public Parks, N. Y | Geographical positions and descriptions of stations between Yonkers and Spuyten Duyvel. |
| 4 | J. J. R. Randall, Rutland, Vt | Latest magnetic declination at Rutland, Vt., with information as to annual change. |
| 4 | General J. E. Slaughter, Cedar Keys, Fla | Unfinished coast chart No. 79, Cedar Keys to Chassahowitzka River, Fla., and of No. 81, Apalachee Bay, Fla. (brought up by hand). |
| 5 | E. P. Austin, Boston, Mass | Predictions of tides for Boston for 1882, to use in a local almanac to be published there. |
| 6 | W. W. Austin, Richmond, Ind | Magnetic declination at Richmond and annual change. |
| 8 | Lieut. R. M. G. Brown, United States Navy | Copy survey Hudson River, three miles above Spuyten Duyvel Creek. |
| 10 | Verplanck Colvin, Superintendent Adirondack Survey | Description of bench-marks at Albany canal locks. |
| 11 | Admiral D. D. Porter, United States Navy | Hydrographic survey Coasters Island Harbor, R. I., 1880. |
| 13 | Gen. Q. A. Gillmore, United States Corps of Engineers | Hydrographic survey Savannah River from upper end of Elba Island to Tybee Roads, scale 1–5,000, 1875. |
| 14 | L. R. Brown, Treasury Department | Heights of positions in or near Loudoun County, Va. |
| 14 | Verplanck Colvin, Superintendent Adirondack Survey | Azimuthal directions from Blueberry Hill to Mount Pharaoh and several other trigonometrical points. |
| 16 | H. D. Whitcomb, Assistant Engineer James River Improvements. | Hydrographic survey James River from City Point to Warwick Bar, 1880. |

## APPENDIX No. 3—Continued.

| Date. | | Name. | Data furnished. |
|---|---|---|---|
| May | 17 | S. T. Abert, civil engineer | Hydrographic survey of Rappahannock River, Va., from Fredericksburg to Corbin's Neck. |
| | 17 | R. Keith, professor mathematics, United States Navy, Easton, Md. | Predictions of tides for Philadelphia for 1882, for publication in the Public Ledger Almanac. |
| | 20 | Allston G. Dayton, surveyor, Philippi, W. Va | Advice respecting magnetic declination. |
| | 20 | Col. W. P. Craighill, United States Corps of Engineers | Hydrographic and topographical survey of 1857, York River, vicinity of Yorktown. |
| | 21 | United States Light-House Board | Unfinished chart, approaches to Isle au Haut Bay and Eggemoggin Reach, Me., scale 1-40,000 (brought up by hand). |
| June | 1 | Capt. W. Arthur, R. N., Bristol, R. I | Distance between the Bristol Ferry Light and Sandy Point Light. |
| | 3 | Mr. William B. Noerr, Treasury Department | Sketch showing changes in the shore-line Rockaway Inlet, L. I. Topographical survey Rockaway Inlet, 1835 and 1855-'56. |
| | 8 | Col. William P. Craighill, United States Corps of Engineers | Description of bench-marks at Annapolis, Md., and at Queenstown, on Chester River, Md. |
| | 8 | Sent to superintendent for transmission | Predictions for San Francisco, in MS., for 1882, 12 pp. |
| | 10 | Lieutenant Caziarc, Acting Signal Officer | Height of freshets at Albany, on the Hudson. |
| | 10 | For the two polar expeditions | Directions for observing tides, both printed and written. |
| | 11 | G. Clinton Gardner, Manager Mexican National Construction Company. | Hydrographic survey, 1875, of Aransas Pass., Tex., scale 1-10,000; also Corpus Christi Pass, scale 1-10,000. |
| | 13 | do | Unfinished proof of coast chart No. 109, Aransas, Copano and part of Corpus Christi Bays, scale 1-80,000 (brought up by hand). |
| | 13 | N. H. Hutton, Engineer Harbor Board, Baltimore | Hydrographic survey mouth of Baltimore Harbor, 1845, scale 1-10,000. |
| | 13 | Col. William P. Craighill, United States Corps of Engineers | Descriptions of bench-marks at Lewes, Del., and at Cambridge, Md. |
| | 13 | do | Hydrographic survey Broad Creek, west side, Kent Island, Chester Bay, 1844, and of Corsica Creek, on Chester River, Md.; of Devil's Island, Thoroughfare and Rock Creek, Md., 1856, 1858; also Skipton Creek, on Wye River, and Brush River, head of Chesapeake Bay, 1846. |
| | 16 | Sylvanus Butler, New Haven | Distances between trigonometrical stations about New Haven. |
| | 17 | do | Chart of New Haven Harbor, scale 1-2,000, with distances given from a number of points as measured from the plane-table sheets. |
| | 18 | E. B. Van Winkle, T. E., Department Public Parks, N. Y. | Chart of Hudson River, N. Y., to Haverstraw, with triangulation center north plotted from Yonkers to Fort Independence. |
| | 18 | Prof. John Milne, F. G. S., of Imperial College of Engineers, Tokio, Japan. | On the different kind of tide-gauges, their cost, and the expenses for using them. |
| | 20 | F. W. Dean, tutor in English, Harvard University | Geographical positions and descriptions of stations on Campobello Island, Canada. |
| | 21 | J. B. Gibboney, County Surveyor, Wytheville, Va | Magnetic information in general and three pamphlets. |
| | 22 | Capt. George Brown, United States Navy | Hydrographic survey Thimble Islands and vicinity, Long Island Sound, 1838. |
| | 24 | General N. Michler, United States Corps of Engineers | Hydrographic survey Jersey Flats, upper New York Bay. |
| | 27 | Lieutenant Gillespie, United States Engineers, Portland, Oreg. | Geographical positions and descriptions of stations, triangulation of Gray's Harbor, Washington Territory. |
| | 28 | J. P. Bogart, engineer, New Haven | Geographical positions of Old Light, New Haven, and of Southwest New Light-House. |
| | 28 | Prof. W. G. Simmons, Wake Forest College, N. C | Geographical position of Raleigh, N. C., and of Washington, D. C. |
| | 28 | W. H. Hall, State Engineer, Sacramento, Cal | Position of Initial Point Mountain, Cal., and Mexican State Boundary on the Pacific. |
| | 29 | James Bogart | Chart of New Haven Harbor, Conn., scale 1-20,000, with distances given from a number of points. |
| | 30 | E. B. Van Winkle, T. E., Department Public Parks, N. Y. | Tracing of topographical sheet of 1859 of the Hudson River between Spuyten Duyvel Creek and Yonkers, showing location of trigonometrical points. |
| | 30 | B. D. Greene, Lieutenant United States Engineers, Charleston, S. C. | Description of bench-marks for Charleston Harbor, S. C. |

# APPENDIX No. 4.

## DRAWING DIVISION.

### *Charts completed or in progress during the year ending June 30, 1881.*

1. Topography. 2. Hydrography. 3. Drawing for photolithographic reproduction. 4. Inking and lettering plane-table sheets. 5. New longitude. 6. Verification.

| Title of charts. | Scale. | Draughtsmen. | Remarks. |
|---|---|---|---|
| ATLANTIC COAST. | | | |
| Sailing charts: | | | |
| No. III, Cape Hatteras to Mosquito Inlet | 1-1, 200, 000 | 2. C. Junken | Additions. |
| No. V, Gulf of Mexico (new edition) | 1-2, 100, 000 | 2. A. Lindenkohl | Completed. |
| PACIFIC COAST. | | | |
| Sailing charts: | | | |
| No. 601, San Diego to San Francisco | 1-1, 200, 000 | 2. T. J. O'Sullivan | Additions. |
| No. 700, Cape Flattery to Dixon Entrance | 1-1, 200, 000 | 2. H. Lindenkohl | Do. |
| No. 701, Dixon Entrance to Cape St. Elias | 1-1, 200, 000 | 2. H. Lindenkohl | Do. |
| No. 702, Ice Bay to Seven Islands | 1-1, 200, 000 | 2. H. Lindenkohl | Do. |
| GENERAL CHARTS OF THE ATLANTIC COAST. | | | |
| No. I, Isle au Haut to Cape Cod (western part) | 1-400, 000 | 2. A. Lindenkohl | Completed. |
| No. II, Cape Ann to Gay Head | 1-400, 000 | 2. A. Lindenkohl | Additions. |
| No. III, Gay Head to Cape Henlopen | 1-400, 000 | 2. A. Lindenkohl | Do. |
| No. IV, Cape May to Cape Henry | 1-400, 000 | 2. A. Lindenkohl | Do. |
| No. V, Cape Henry to Cape Lookout | 1-400, 000 | 1 and 2. A. Lindenkohl. 2. H. Lindenkohl. 2 and 5. C. Junken. | Do. |
| No. VI, Cape Hatteras to Cape Romain | 1-400, 000 | 2. A. Lindenkohl | Do. |
| No. VII, Cape Romain to Saint Mary's Entrance | 1-400, 000 | 2. A. Lindenkohl | Do. |
| No. XII, Tampa Bay to Cape San Blas | 1-400, 000 | 1. A. Lindenkohl. 6. P. Erichsen | Do. |
| No. XIII, Cape San Blas to Mississippi Passes | 1-400, 000 | 2. C. Junken | Do. |
| COAST CHARTS OF THE ATLANTIC COAST. | | | |
| No. 3, Petit Manan to Naskeag Point (including Frenchman's and Blue Hill Bays). | 1-80, 000 | 1. E. H. Fowler. 2. A. Lindenkohl. 2. H. Lindenkohl. 6. C. Junken. | |
| No. 4, Penobscot Bay, Me | 1-80, 000 | 2. T. J. O'Sullivan. 2. A. Lindenkohl. 2. H. Lindenkohl. | Completed. |
| No. 13, Narragansett Bay, R. I | 1-80, 000 | 2. C. Junken | |
| No. 20, New York Bay and Harbor | 1-80, 000 | 1 and 2. H. Lindenkohl | |
| No. 28, Isle of Wight to Chincoteague Inlet | 1-80, 000 | 2. A. Lindenkohl | |
| No. 31, Entrance to Chesapeake, Hampton Roads, &c | 1-80, 000 | 1. H. Lindenkohl | |
| No. 42, Pamplico Sound. (Eastern sheet.—Roanoke Island to Hatteras Inlet.) | 1-80, 000 | 2. A. Lindenkohl | |
| No. 58, Cumberland Sound, Saint John's River, &c., Fla | 1-80, 000 | 6. P. Erichsen | Completed. |
| No. 61, Cape Canaveral and vicinity, Fla | 1-80, 000 | 1 and 2. H. Lindenkohl | Do. |
| No. 70, Key West to Rebecca Shoal, Fla | 1-80, 000 | 5. C. Junken | Additions. |
| No. 71, Marquesas Keys to the Tortugas, Fla | 1-80, 000 | 5. C. Junken | Do. |
| No. 75, Charlotte Harbor, Fla | 1-80, 000 | 2. A. Lindenkohl | |
| No. 81, Apalachee Bay, Fla | 1-80, 000 | 6. P. Erichsen | |
| No. 83, Apalachicola Bay to Cape San Blas, Fla | 1-80, 000 | 6. P. Erichsen | |
| No. 84, Saint Joseph's and Saint Andrew's Bays, Fla | 1-80, 000 | 6. R. E. Peary | Completed. |
| No. 107, Matagorda and Lavaca Bays, Tex | 1-80, 000 | 2. C. Junken | Do. |
| No. 109, Aransas and Copano Bays, Tex | 1-80, 000 | 2. C. Junken | Do. |
| HARBOR CHARTS. | | | |
| No. 306, Frenchman's Bay and Some's Sound, Me | 1-40, 000 | 1 and 2. A. Lindenkohl. 2. C. Junken | Completed. |
| No. 307, Blue Hill and Union River Bays, Me | 1-40, 000 | 1 and 2. C. Junken. 1. E. J. Sommer | Continued. |
| No. 308, Approaches to Blue Hill Bay and Eggemoggin Reach, Me. | 1-40, 000 | 2. C. Junken | Completed. |
| No. 310, Penobscot Bay, Me | 1-40, 000 | 1. T. J. O'Sullivan. 5. A. Lindenkohl | Additions. |

## APPENDIX No. 4—Continued.

| Title of charts. | Scale. | Draughtsmen. | Remarks. |
|---|---|---|---|
| No. 311, Penobscot River and Belfast Bay, Me. | 1-40, 000 | 1 and 2. A. Lindenkohl. 1. H. Lindenkohl. | Completed. |
| No. 337, Boston Harbor, Mass | 1-40, 000 | 2. C. Junken | Additions. |
| No. 353, Narragansett Bay, R. I. | 1-40, 000 | 2. C. Junken | Do. |
| No. 363, Black Rock and Bridgeport Harbors, Conn | 1-20, 000 | 1. T. J. O'Sullivan. 1. L. Karcher. 1. A. Lindenkohl. | Commenced. |
| No. 553, Lake Champlain, Rouse's Point to Cumberland Head. | 1-40, 000 | 2. C. Junken | Additions. |
| No. 554, Lake Champlain, Cumberland Head to Ligonier Point. | 1-40, 000 | 2. C. Junken | Do. |
| No. 564, Raritan River (Sheet No. 1. South Amboy to Crabb Island). | 1-15, 000 | 2. E. H. Fowler | Do. |
| No. 384, Patapsco River, Md | 1-60, 000 | 2. H. Lindenkohl | Do. |
| No. 404*a*, Norfolk City to Lynn Haven River, Va. | 1-20, 000 | 3. T. J. O'Sullivan | Photolithograph: completed. |
| No. 401*a*, James River (Sheet No. 1. Newport News to Deep-Water Light). | 1-40, 000 | 1. A. E. Burton. 2. C. Junken. 6. P. Erichsen. | Additions. |
| No. 401*b*, James River (Sheet No. 2. Point of Shoals Light to Sloop Point). | 1-40, 000 | 2. C. Junken. 6. R. E. Peary. 6. P. Erichsen. | Do. |
| No. 401*c*, James River (Sheet No. 3. Sloop Point to City Point). | 1-40, 000 | 2. C. Junken. 6. R. E. Peary | Do. |
| No. —, Upper Potomac River (Great Falls to Shepherdstown). | 1-40, 000 | 1. E. H. Fowler | Do. |
| No. 430*a*, Bull's Bay, S. C | 1-40, 000 | 1. A. E. Burton. 6. P. Erichsen | Additions. |
| No. 441, Ossabaw Sound, Ga | 1-30, 000 | 5. C. Junken | Do. |
| No. 455*a*, St. John's River, Fla. (Jacksonville to Lake Monroe). | 1-80, 000 | 3. H. Lindenkohl | Photolithograph. |
| No. 510, Mississippi River (Sheet No. 12. Chapman Plantation to Brilliant Point). | 1-20, 000 | 2. H. Lindenkohl | Photolithograph; additions. |
| No. 510, Mississippi River (Sheet No. 13. St. James Estate to Point Houmas). | 1-20, 000 | 2. H. Lindenkohl | Do. Do. |
| No. 623, San Pablo Bay, Cal | 1-50, 000 | 2. C. Junken | Additions. |
| No. 626, Suisun Bay, Cal | 1-40, 000 | 2. C. Junken | Do. |
| No. 670, Newport Entrance, Los Angeles County, Cal | 1-15, 000 | 3. E. J. Sommer | Photolithograph: completed. |
| No. 692, Shelter Cove, Cal | 1-10, 000 | 3. H. Lindenkohl | Do. Do. |
| No. 693, Timber Cove, Cal | 1-5, 000 | 3. H. Lindenkohl | Do. Do. |
| No. 694, Fort Ross Cove, Cal | 1-5, 000 | 3. H. Lindenkohl | Do. Do. |
| No. 691, Alseya Harbor Entrance, Oreg | 1-6, 000 | 3. E. J. Sommer | Do. Do. |
| No. 639*bis*, Entrance to the Columbia River, Oreg | 1-40, 000 | 3. H. Lindenkohl | Do. Do. |
| No. 708, Sitka Harbor, Alaska | 1-15, 000 | 1, 2. H. Lindenkohl. 2. C. Junken | Do. Do. |
| PLANE-TABLE SHEETS. | | | |
| Franklin and Hog Bays, Me. (2 sheets) | 1-10, 000 | 4. E. J. Sommer. 4. A. B. Graham | |
| Bartlett's and Long Islands, Me | 1-10, 000 | 4. T. J. O'Sullivan | |
| Skillings River, Me | 1-10, 000 | 4. R. E. Peary. T. J. O'Sullivan | |
| Head of Union River Bay to Ellsworth, Me | 1-10, 000 | 4. A. E. Burton. T. J. O'Sullivan | |
| St. Croix River, Me | 1-10, 000 | 4. R. E. Peary | |
| Lamoine and Hog Bay, Me | 1-10, 000 | 4. B. Bradbury. R. E. Peary. E. H. Fowler. | |
| Dyer's Neck, Me | 1-10, 000 | 4. T. J. O'Sullivan | |
| Jordan River and vicinity, Me | 1-10, 000 | 4. E. H. Fowler | |
| Chatham Beaches, Mass | 1-10, 000 | 4. R. E. Peary | |
| Plymouth, Mass. (duplicating) | 1-10, 000 | 4. A. E. Burton | |
| Lake Champlain (2 sheets) | 1-10, 000 | 4. P. Erichsen. R. E. Peary | |
| Babylon and vicinity, L. I | 1-10, 000 | 4. E. H. Fowler | |
| Eastern part of Jamaica Bay, L. I | 1-10, 000 | 4. A. B. Graham. H. Lindenkohl | |
| Middle part of Jamaica Bay, L. I | 1-10, 000 | 4. A. E. Burton | |
| Rockaway Beach, L. I | 1-10, 000 | 4. A. E. Burton | |
| Rockaway Inlet, L. I | 1-20, 000 | 4. T. J. O'Sullivan | |
| Jamaica Bay, L. I | 1-10, 000 | 4. R. E. Peary | |
| Oak Island Beach, L. I | 1-10, 000 | 4. T. J. O'Sullivan | |
| Eastern end of Long Beach, L. I | 1-10, 000 | 4. R. E. Peary | |
| Western end of Jones' Beach, L. I | 1-10, 000 | 4. A. E. Burton | |

## APPENDIX No. 4—Continued.

| Title of charts. | Scale. | Draughtsmen. | Remarks. |
|---|---|---|---|
| Hempstead Bay, L. I | 1–10, 000 | 4. R. E. Peary | |
| Hudson River, from Cold Spring to Newburg | 1–10, 000 | 4. A. E. Burton | |
| Hereford Inlet, coast of New Jersey | 1–10, 000 | 4. H. Lindenkohl | |
| Delaware River, Fort Mifflin to Chester (3 sheets) | 1–5, 000 | 4. H. Lindenkohl. E. J. Sommer | |
| Cape May City, N. J. | 1–10, 000 | 4. T. J. O'Sullivan | |
| Norfolk City Front, Va | 1–10, 000 | 4. P. Erichsen. R. E. Peary | |
| James River, below Richmond, Va. (2 sheets) | 1–10, 000 | 4. E. H. Fowler. A. B. Graham. T. J. O'Sullivan. | |
| Cape Charles, Va | 1–20, 000 | 4. A. B. Graham | |
| Mob Jack Bay, Va | 1–20, 000 | 4. A. B. Graham | |
| Indian River, Fla. (part of) | 1–20, 000 | 4. A. E. Burton | |
| Mississippi River, below Donaldsonville, La. (3 sheets) | 1–20, 000 | 4. T. J. O'Sullivan | |
| Laguna Madre, Tex. (3 sheets) | 1–20, 000 | 4. T. J. O'Sullivan. A. E. Burton. E. H. Fowler. R. E. Peary. | |
| North of Point Arguello, Cal | 1–10, 000 | 4. T. J. O'Sullivan | |
| Lompoc Landing to Shuman's Cañon, Cal | 1–10, 000 | 4. E. J. Sommer | |
| North of Point Conception, Cal | 1–10, 000 | 4. T. J. O'Sullivan | |
| Point Sur and vicinity, Cal | 1–10, 000 | 4. R. E. Peary | |
| Columbia River to Columbia City, Oreg | 1–10, 000 | 4. T. J. O'Sullivan | |
| Puget Sound (part of), Washington Territory | 1–10, 000 | 4. R. E. Peary | |
| MISCELLANEOUS | | | |
| Map showing progress of coast and geodetic work | 1–5, 000, 000 | A. Lindenkohl. H. Lindenkohl | Completed. |
| Scheme to illustrate the triangulation and reconnaissance of the interior of the United States. | 1–7, 000, 000 | L. Karcher. H. Lindenkohl | |
| Model of the Gulf of Mexico | 1–2, 400, 000 | A. Lindenkohl | Completed. |
| Progress sketches: New Hampshire, Kentucky, Indiana, and Wisconsin. | 1–1, 000, 000 | H. Lindenkohl | |
| Pulpit Cove, tide-station, Me | 1–400, 000 | H. Lindenkohl | Completed. |
| Triangulation of the Mississippi River | 1–200, 000 | 3. L. Karcher. 3. T. J. O'Sullivan | Commenced. |
| Shore-line of coast, from Indian River to Cape Florida | 1–200, 000 | A. Lindenkohl | |
| General-progress sketches, work of 1878–'79 | | A. Lindenkohl | |
| Chart of the West Indies | | 1, 2, 3. T. J. O'Sullivan | Photolithograph; completed. |
| Plan of a new base-line apparatus | | P. Erichsen | Completed. |
| Drawing of leveling instrument No. 3 and target | | P. Erichsen | Do. |
| Pendulum drawings | | P. Erichsen | Do. |
| Diagrams of telegraph apparatus | | A. E. Burton | Do. |
| Magnesium light, sketches | | 3. T. J. O'Sullivan. | Photolithograph; completed. |
| Plan of rotation comparing apparatus | | P. Erichsen | Completed. |
| Plan of Sigsbee's deep-sea apparatus | | P. Erichsen | Do. |
| Telegraphic longitude stations | | T. J. O'Sullivan | Do. |
| Transit of Mercury, sketches | | T. J. O'Sullivan | Do. |
| Line and end comparator | | P. Erichsen | Do. |
| Diagrams to illustrate article on projections | | A. E. Burton. T. J. O'Sullivan | Do. |

# APPENDIX No. 5.

## ENGRAVING DIVISION.

*Plates completed, continued, or commenced during the year ending June 30, 1881.*

1. Outlines. 2. Topography. 3. Sanding. 4. Lettering.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Engravers. | When published. |
|---|---|---|---|---|---|
| | | COMPLETED. | | | |
| B | 1523 | Sailing chart B, Cape Hatteras to Key West (upper). | 1-1, 200, 000 | 4. J. G. Thompson and A. C. Ruebsam ...... | December, 1880. |
| B | 1524 | Sailing chart B, Cape Hatteras to Key West (lower). | 1-1, 200, 000 | 4. J. G. Thompson and A. C. Ruebsam ....... | December, 1880. |
| 6 | 1635 | General coast chart No. 1, Quoddy Head to Cape Cod (west sheet), Isle au Haut to Cape Cod. | 1-400, 000 | 4. E. A. Maedel, A. Petersen, and T. Wasserbach. | March, 1881. |
| 12 | 1350 | General coast chart No. 7, Cape Romain to Saint Mary's entrance. | 1-400, 000 | 4. E A. Maedel, E. H. Sipe, and T. Wasserbach. | July, 1880. |
| 104 | 1114 | Coast chart No. 4, Penobscot Bay............. | 1-80, 000 | 1 and 2. W. A. Thompson. 4. A. Petersen and J. G. Thompson. | October, 1880. |
| 139 | 1449 | Coast chart No. 39, Oregon Inlet to Cape Hatteras. | 1-80, 000 | 4. J. G. Thompson . .... .................... | May, 1881. |
| 170 | 1375 | Coast chart No. 70 Key West to Rebecca Shoal. | 1-80, 000 | 4. E. A. Maedel, E. H. Sipe, and A. C. Ruebsam. | October, 1880. |
| 177 | 1441 | Coast chart No. 77, Tampa Bay............... | 1-80, 000 | 3. W. A. Thompson. 4. J. G. Thompson and T. Wasserbach. | January, 1881. |
| 555 | 1336 | Harbor chart, Lake Champlain, No. 3, Ligonier Point to Coles Bay. | 1-50, 000 | 4. E. A. Maedel and A. C. Ruebsam......... | December, 1880. |
| 556 | 1337 | Harbor chart, Lake Champlain, No. 4, Coles Bay to Whitehall. | 1-50, 000 | 4. E. A. Maedel and A. C. Ruebsam....... | December, 1880. |
| A | 1357 | Sailing chart A, Cape Sable to Cape Hatteras (upper). Edition of 1881. | 1-1, 200, 000 | 4. A. C. Ruebsam ........................ | January, 1881. |
| A | 1367 | Sailing chart A, Cape Sable to Cape Hatteras (lower). Edition of 1881. | 1-1, 200, 000 | 4. A. Petersen, E. H. Sipe, and A. C. Ruebsam. | January, 1881. |
| 15 | 1081 | General coast chart No. 10, Straits of Florida. Edition of 1881. | 1-400, 000 | 3. W. A. Thompson. 4. J. G. Thompson and T. Wasserbach. | June, 1881. |
| 113 | 1371 | Coast chart No. 13, coast from Monomoy and Nantucket Shoals to Block Island, western sheet, Cuttyhunk to Block Island, including Narragansett Bay. Edition of 1880. | 1-80, 000 | 2. W. A. Thompson. 4. T. Wasserbach. | March, 1880. |
| 120 | 1404 | Coast chart No. 20, New York Bay and Harbor Edition of 1881. | 1-80, 000 | 3. H. M. Knight. 4. T. Wasserbach and A. C. Ruebsam. | May, 1881. |
| 129 | 1286 | Coast chart No. 29, Chincoteague Inlet to Hog Island Light. Edition of 1880. | 1-80, 000 | 4. A. C. Ruebsam ........... ........... | July, 1880. |
| 206 | 1210 | Coast chart No. 106, Oyster Bay to Matagorda Bay. Edition of 1881. | 1-80, 000 | 3. W. A. Thompson. 4. E. A. Maedel and A. Petersen. | January, 1881. |
| 317 | 1333 | Harbor chart, Winter Harbor. Edition of 1881 | 1-20, 000 | 4. J. G. Thompson ........................ | April, 1881. |
| 386 | 784 | Harbor chart, Patuxent River (lower). Edition of 1880. | 1-60, 000 | 4. A. C. Ruebsam ....... ................ | January 1880. |
| 387 | 863 | Harbor chart, Patuxent River, Point Judith to Nottingham. Edition of 1881. | 1-30, 000 | 3. W. H. Davis. 4. E. A. Maedel, A. Petersen, and A. C. Ruebsam. | May, 1881. |
| 406 | 851 | Harbor chart, North Landing River. Edition of 1880. | 1-40, 000 | 4. William Smith ......................... | December, 1880. |
| 430*a* | 1590 | Harbor chart, Bulls Bay, South Carolina. Edition of 1881. | 1-40, 000 | 2. H. C. Evans. 3. W. A. Thompson. 4. E. A. Maedel. | June, 1881. |
| 435 | 1173 | Harbor chart, Bull and Cambahee Rivers. Edition of 1880. | 1-40, 000 | 4. T. Wasserbach and A. C. Ruebsam ...... | March, 1880. |
| 471*a* | 1475 | Harbor chart, Tortugas Harbor and approaches. Edition of 1880. | 1-40, 000 | 3. H. M. Knight and W. A. Thompson. 4. J. G. Thompson. | July, 1880. |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Engravers. | When published. |
|---|---|---|---|---|---|
| | | COMPLETED—Continued. | | | |
| 474 | 1121 | Harbor chart, Charlotte Harbor. Edition of 1880. | 1–40, 000 | 4. T. Wasserbach and A. C. Ruebsam........ | March, 1880. |
| 475 | 1138 | Harbor chart, Caloosa entrance. Edition of 1881. | 1–40, 000 | 4. J. G. Thompson and W. H. Davis........ | April, 1881. |
| 490 | 1391 | Harbor chart, entrance to Pensacola Bay. Edition of 1881. | 1–40, 000 | 3 and 4. H. M. Knight........................ | January, 1881. |
| 700 | 1083 | Sailing chart, northwest coast, sheet No. 1, Cape Flattery to Dixon entrance. Edition of 1880. | 1–1, 200, 000 | 1. E. H. Sipe and T. Wasserbach. 4. E. A. Maedel. | October, 1880. |
| 702 | 1133 | Sailing chart, northwest coast, sheet No. 3, Icy Bay to Seven Islands Edition of 1880. | 1–1, 200, 000 | 1 and 4. T. Wasserbach .................. | October, 1880. |
| | | ATLANTIC COAST PILOT CHARTS, VOLUME 3. | | | |
| ...... | 1591 | Barnegat Inlet to New Inlet ................ | 1–80, 000 | Completed .............................. | December, 1880. |
| ...... | 1592 | New Inlet to Absecom Inlet ................ | 1–80, 000 | Completed .............................. | December, 1880. |
| ...... | 1613 | Delaware entrance ........................ | 1–400, 000 | Completed .............................. | December, 1880. |
| ...... | 1616 | Chesapeake Bay (lower) .................... | 1–400, 000 | Completed .............................. | December, 1880. |
| ...... | 1617 | Chesapeake Bay (upper) .................... | 1–400, 000 | Completed .............................. | December, 1880. |
| | | COMPLETED ATLANTIC COAST PILOT VIEWS. | | | *Completed.* |
| ...... | 1604 | Approaches to Narragansett Bay from eastward and westward. | ............ | ............................................ | September 18, 1880. |
| ...... | 1605 | Entrance to New London Harbor from the southward. | ............ | ............................................ | September 24, 1880. |
| ...... | 1606 | Off south entrance to Quick's Hole ............ | ............ | ............................................ | August 11, 1880. |
| ...... | 1607 | Entrance to Gardiner Bay from the southward | ............ | ............................................ | August 7, 1880. |
| ...... | 1608 | Off mouth of Connecticut River ............ | ............ | ............................................ | July 16, 1880. |
| ...... | 1609 | Block Island from the eastward ............ | ............ | ............................................ | September 29, 1880. |
| ...... | 1612 | Cape Cod from the northward, Highland Lights | ............ | ............................................ | August 26, 1880. |
| ...... | 1615 | Tempes Nob (Buzzard's Bay), Great Hill (Buzzard's Bay). | ............ | ............................................ | September 1, 1880. |
| ...... | 1619 | Off Currituck Beach, Nag's Head, Bodie's Island, Oregon Inlet. | ............ | ............................................ | October 14, 1880. |
| ...... | 1621 | Cape Hatteras from the southward, eastward, and northward. | ............ | ............................................ | October 27, 1880. |
| ...... | 1622 | Hatteras Inlet, Ocracoke Inlet from the eastward and southward. | ............ | ............................................ | November 9, 1880. |
| ...... | 1624 | Cape Lookout from the eastward and southward | ............ | ............................................ | November 17, 1880. |
| ...... | 1627 | Beaufort, Beaufort City, Morehead City ...... | ............ | ............................................ | January 4, 1881. |
| ...... | 1628 | Cape Fear and Smith's Island from the eastward. | ............ | ............................................ | June 16, 1881. |
| ...... | 1636 | Entrance to Winyah Bay and Georgetown Harbor. | ............ | ............................................ | May 28, 1881. |
| ...... | 1516 | Topographical specimen, San Luis Obispo .... | 1–10, 000 | ............................................ | August, 1880. |
| ...... | 1648 | Topographical specimen, curves, San Luis Obispo. | 1–10, 000 | ............................................ | August 3, 1880. |
| ...... | 1599 | Topographical specimen, Harper's Ferry (lower). | 1–10, 000 | ............................................ | June 10, 1880. |
| ...... | 1656 | Topographical specimen, Harper's Ferry, lower curves. | 1–10, 000 | ............................................ | May 9, 1881. |
| ...... | 1633 | Surface temperatures, Bering Strait, August and September, 1880. | ............ | ............................................ | February 14, 1881. |
| | | CONTINUED. | | | |
| 11 | 1429 | General coast chart No. 6, Cape Hatteras to Cape Romain. | 1–400, 000 | 1 and 2. W. A. Thompson. 4. J. G. Thompson and A. Petersen. | |
| 18 | 1043 | General coast chart No. 13, Cape San Blas to Mississippi Passes. | 1–400, 000 | 4. A. Petersen and A. C. Ruebsam. | |
| 103 | 1113 | Coast chart No. 3, Frenchman's and Blue Hill Bays. | 1–80, 000 | 1 and 2. J. Enthoffer. 4. E. A. Maedel and J. G. Thompson. | |
| 143 | 1190 | Coast chart No. 43, Pamplico Sound (middle sheet), Ocracoke Inlet to mouth of Pamplico River. | 1–80, 000 | 4. A. C. Ruebsam ............................ | |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Engravers. | When published. |
|---|---|---|---|---|---|
| | | CONTINUED—Continued. | | | |
| 153 | 1503 | Coast chart No. 53, Winyah Bay to Long Island. | 1-80, 000 | 1 and 2. A. Sengteller. 4. J. G. Thompson. | |
| 158 | 1234 | Coast chart No. 58, Cumberland Sound, Saint John's River, &c. | 1-80, 000 | 3. W. A. Thompson. 4. E. A. Maedel, A. Petersen, J. G. Thompson, A. C. Ruebsam. | |
| 159 | 1411 | Coast chart No. 59, Saint Augustine Inlet to Halifax River. | 1-80, 000 | 3. H. M. Knight. 4. A. C. Ruebsam | |
| 160 | 1526 | Coast chart No. 60, Halifax River to Mosquito Lagoon. | 1-80, 000 | 1 and 2. H. C. Evans. 3. H. M. Knight. 4. E. A. Maedel and F. Courtenay. | |
| 171 | 1407 | Coast chart No. 71, Rebecca Shoal to Tortugas | 1-80, 000 | 1, 2, and 3. W. A. Thompson. 3. H. M. Knight. 4. E. A. Maedel and J. G. Thompson. | |
| 181 | 1450 | Coast chart No. 81, Apalachee Bay, Fla | 1-80, 000 | 3. H. M. Knight, F. W. Benner | |
| 182 | 1447 | Coast chart No. 82, Apalachee Bay and Saint George's Sound. | 1-80, 000 | 4. E. A. Maedel | |
| 183 | 1347 | Coast chart No. 83, Apalachicola Bay to Cape San Blas. | 1-80, 000 | 3 and 4. A. C. Ruebsam | |
| 185 | 1498 | Coast chart No. 85, Saint Andrew's Bay to Choctawhatchee Inlet. | 1-80, 000 | 4. E. H. Sipe | |
| 192 | 1537 | Coast chart No. 92, Chandeleur and Isle Breton Sounds. | 1-80, 000 | 4. H. M. Knight | |
| 195 | 1314 | Coast chart No. 95, Mississippi River Forts to New Orleans. | 1-80, 000 | 1 and 2. A. Sengteller. 4. J. G. Thompson | |
| 204 | 1316 | Coast chart No. 104, Galveston Bay | 1-80, 000 | 3. F. W. Benner | |
| 208 | 1247 | Coast chart No. 108, Pass Cavallo, Lavaca, and San Antonio Bays. | 1-80, 000 | 4. E. A. Maedel, A. Petersen | |
| 209 | 1248 | Coast chart No. 109, Aransas and Copano Bays. | 1-80, 000 | 4. E. A. Maedel | |
| 306 | 1186 | Harbor chart, Frenchman's Bay and Somes Sound. | 1-40, 000 | 1 and 2. R. F. Bartle. 4. A. Petersen, J. G. Thompson, and E. H. Sipe. | |
| 307 | 1265 | Harbor chart, Blue Hill and Union River Bays. | 1-40, 000 | 1, 2, and 3. H. C. Evans. 4. A. Petersen, J. G. Thompson, and T. Wasserbach. | |
| 308 | 1376 | Harbor chart, approaches to Blue Hill Bay and Eggemoggin Reach. | 1-10, 000 | 1 and 4. J. G. Thompson | |
| 309 | 1195 | Harbor chart, East Penobscot Bay | 1-40, 000 | 3. W. A. Thompson. 4. E. A. Maedel and A. Petersen. | |
| 311 | 1259 | Harbor chart, Penobscot River and Belfast Bay. | 1-40, 000 | 1 and 2. H. C. Evans. 3. W. A. Thompson. 4. E. A. Maedel, A. Petersen, and J. G. Thompson. | |
| 360 | 1544 | Harbor chart, mouth of Connecticut River | 1-20, 000 | | |
| 401*a* | 1445 | Harbor chart, James River, No. 1, Hampton Roads to Point of Shoals. | 1-40, 000 | 1 and 2. J. Enthoffer. 3. H. M. Knight. 4. E. A. Maedel, J. G. Thompson; and 1, 2, and 3. W. A. Thompson. | |
| 401*b* | 1555 | Harbor chart, James River, No. 2, Point of Shoals to Sandy Point. | 1-40, 000 | 3. H. M. Knight. 4. E. A. Maedel and F. Courtenay. | |
| 401*c* | 1495 | Harbor chart, James River No. 3, Sandy Point to City Point. | 1-40, 000 | 3. H. M. Knight. 4. E. A. Maedel and J. G. Thompson. | |
| 671 | 1534 | General coast chart, San Diego to Point Vincent. | 1-200, 000 | 4. A. Petersen | |
| 672 | 1228 | General coast chart, Point Vincent to Point Conception. | 1-200, 000 | 4. A. C. Ruebsam | |
| 621*a* | 1532 | Harbor chart, San Francisco Bay entrance | 1-40, 000 | 2. J. Enthoffer. 4. A. Petersen | |
| 641*b* | 1533 | Harbor chart, Columbia River, No. 4 | 1-40, 000 | 1. W. A. Thompson. 2. R. F. Bartle. 4. E. A. Maedel, and A. Petersen. | |
| | | COMMENCED. | | | *When commenced.* |
| 17 | 1603 | General coast chart No. 12, Tampa Bay to Cape San Blas. | 1-400, 000 | 1 and 2. R. F. Bartle. 4. J. G. Thompson | July 20, 1880. |
| 1 | 1602 | Coast chart No. 61, Mosquito Inlet to Cape Cañaveral. | 1-80, 000 | 1 and 2. H. C. Evans. 4. J. G. Thompson | July 12, 1880. |
| 184 | 1601 | Coast chart No. 84, Saint Joseph's Bay to Saint Andrew's Bay. | 1-80, 000 | 1 and 2. R. F. Bartle. 4. J. G. Thompson | July 15, 1880. |
| | 1618 | Progress sketch, east coast of Florida, Indian River to Cape Florida. | 1-200, 000 | 1 and 4. E. H. Sipe | October 6, 1880. |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Engravers. | When published. |
|---|---|---|---|---|---|
| | | COMMENCED—Continued. | | | |
| ...... | 1630 | Progress sketch, sketch of general progress (eastern sheet) Atlantic. | 1–5, 000, 000 | 1, 2, and 4. J. G. Thompson | November 9, 1880. |
| ...... | 1631 | Progress sketch, sketch of general progress (western sheet) Pacific. | 1–5, 000, 000 | 1 and 4. A. Petersen. 2. J. G. Thompson | November 9, 1880 |
| | | ALASKA COAST PILOT CHARTS. | | | |
| ...... | 1565 | The Inland Passage, Cape Mudge to Nahwitti Bar. | | | July, 1880. |
| ...... | 1566 | The Inland Passage, Queen Charlotte to Fitzhugh Sound. | | | July, 1880. |
| ...... | 1567 | Point Walker to Wanson Bay | | | July, 1880. |
| ...... | 1568 | Wake Island to Chatham Sound | | | July, 1880. |
| ...... | 1569 | Dixon entrance and vicinity | | | July, 1880. |
| ...... | 1570 | Portland Canal and Observatory Inlet | | | July, 1880. |
| ...... | 1571 | Behm Canal and Clarence Strait | | | July, 1880. |
| ...... | 1572 | Wolf Rock to Cape Decision | | | July, 1880. |
| ...... | 1573 | Sumner Strait and adjacent estuaries | | | July, 1880. |
| ...... | 1574 | Fedrick Sound, Stephen's Passage, and part of Chatham Strait. | | | July, 1880. |
| ...... | 1575 | Sandy Bay to Cape Edward | | | July, 1880. |
| ...... | 1576 | Northern border of the Alexander Archipelago | | | July, 1880. |
| ...... | 1577 | Lynn Canal and Chilkaht River | | | July, 1880. |
| ...... | 1578 | Lituza Bay to Yakatan Bay | | | July, 1880. |
| | | ALASKA COAST PILOT VIEWS. | | | |
| ...... | 1644 | Entrance to Coghlan Anchorage, Finlayson Channel and entrance to Met-la-kat-la Bay. | | | July, 1880. |
| ...... | 1645 | Sitka | | | July, 1880. |
| ...... | 1646 | Observatory Inlet and Noas Bay | | | July, 1880. |
| ...... | 1647 | Table and Egg Islands, Egg and Table Islands, Cape Calvert, and entrance to Welcome Harbor. | | | July, 1880. |

## *Standard printing plates having received additions and corrections from July* 1, 1880, *to June* 30, 1881.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Dates of last corrections and additions. |
|---|---|---|---|---|
| A | 1357 | Sailing chart A, Cape Sable to Cape Hatteras, upper | 1–1, 200, 000 | June 25, 1881. |
| A | 1367 | Sailing chart A, Cape Sable to Cape Hatteras, lower | 1–1, 200, 000 | June 25, 1881. |
| 2 | 976 | Sailing chart No. 2, Nantucket to Cape Hatteras | 1–1, 200, 000 | July 28, 1880. |
| | 977 | Sailing chart No. 3, Cape Hatteras to Mosquito Inlet | 1–1, 200, 000 | January 28, 1881. |
| 4 | 989 | Sailing chart No. 4, Mosquito Inlet to Key West, &c | 1–1, 200, 000 | July 30, 1880. |
| 5 | 1453 | Sailing chart No. 5, Key West to the Rio Grande | 1–1, 200, 000 | January 20, 1881. |
| 5 | 1458 | Sailing chart No. 5, Key West to the Rio Grande | 1–1, 200, 000 | January 20, 1881. |
| C | 1459 | Sailing chart C, Gulf of Mexico | 1–1, 200, 000 | December 20, 1880. |
| 8 | 1392 | General coast chart No. 3, Gay Head to Cape Henlopen | 1–400, 000 | March 9, 1881. |
| 9 | 1183 | General coast chart No. 4, Cape May to Cape Henry | 1–400, 000 | May 12, 1881. |
| 10 | 1039 | General coast chart No. 5, Cape Henry to Cape Lookout, original | 1–400, 000 | Plate in hand. |
| 10 | 1147 | General coast chart No. 5, Cape Henry to Cape Lookout, standard | 1–400, 000 | March 17, 1881. |
| 12 | 1350 | General coast chart No. 7, Cape Romain to Saint Mary's entrance | 1–400, 000 | September 2, 1880. |
| 15 | 1081 | General coast chart No. 10, Straits of Florida | 1–400, 000 | June 26, 1881. |
| 11 | 1429 | General coast chart No. 6, Cape Hatteras to Cape Romain | 1–400, 000 | March 12, 1881. |
| 104 | 1114 | Coast chart No. 4, Penobscot Bay | 1–80, 000 | May 12, 1881. |
| 109 | 1181 | Coast chart No. 9, Boston Bay and approaches | 1–80, 000 | November 11, 1880. |
| 110 | 1199 | Coast chart No. 10, Cape Cod Bay | 1–80, 000 | June 29, 1881. |
| 111 | 1402 | Coast chart No. 11, Nantucket Shoals to Muskeget Channel | 1–80, 000 | June 7, 1881. |
| 113 | 1371 | Coast chart No. 13, Cuttyhunk to Block Island, &c | 1–80, 000 | March 3, 1881. |
| 114 | 1363 | Coast chart No. 14, Long Island Sound, Point Judith, and Block Island to Plum Island | 1–80, 000 | June 15, 1881. |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Dates of last corrections and additions. |
|---|---|---|---|---|
| 115 | 1419 | Coast chart No. 15, Plum Island to Welch's Point | 1-80, 000 | June 28, 1881. |
| 116 | 1473 | Coast chart No. 16, Welch's Point to New York | 1-80, 000 | March 24, 1881. |
| 117 | 979 | Coast chart No. 17, southern coast of Long Island, eastern sheet, Block Island, Montauk Point, &c. | 1-80, 000 | May 6, 1881. |
| 118 | 865 | Coast chart No. 18, Southern coast of Long Island, middle sheet, Napeague Beach to Forge River. | 1-80, 000 | August 26, 1880. |
| 119 | 866 | Coast chart No. 19, southern coast of Long Island, western sheet, Great South Bay, Fire Island, and Long Beaches. | 1-80, 000 | July 6, 1880. |
| 120 | 1404 | Coast chart No. 20, New York Bay and Harbor | 1-80, 000 | May 27, 1881. |
| 121 | 1535 | Coast chart No. 21, Sandy Hook to Barnegat Inlet | 1-80, 000 | May 10, 1881. |
| 122 | 1536 | Coast chart No. 22, Barnegat Inlet to Absecon Inlet | 1-80, 000 | August 7, 1880. |
| 123 | 1582 | Coast chart No. 23, Absecon Inlet to Cape May | 1-80, 000 | April 12, 1881. |
| 127 | 1200 | Coast chart No. 27, Cape May to Isle of Wight | 1-80, 000 | December 7, 1880. |
| 128 | 1230 | Coast chart No. 28, Isle of Wight to Chincoteague Inlet | 1-80, 000 | Plate in hand. |
| 129 | 1286 | Coast chart No. 29, Chincoteague Inlet to Hog Island Light | 1-80, 000 | July 3, 1880. |
| 130 | 1287 | Coast chart No. 30, Hog Island Light to Cape Henry | 1-80, 000 | February 2, 1881. |
| 131 | 1219 | Coast chart No. 31, Chesapeake Bay, first series, sheet 1, entrance to Chesapeake, Hampton Roads, &c. | 1-80, 000 | June 30, 1881. |
| 134 | 1227 | Coast chart No. 34, Chesapeake Bay, second series, sheet 1, Potomac River to Choptank River. | 1-80, 000 | July 10, 1880. |
| 137 | 1444 | Coast chart No. 37, Cape Henry to Currituck Beach | 1-80, 000 | July 8, 1880. |
| 144 | 1188 | Coast chart No. 44, Pamplico Sound, sheet 1, Pamplico River | 1-80, 000 | January 17, 1881. |
| 144 | 1260 | Coast chart No. 44, Pamplico Sound, sheet 1, Pamplico River | 1-80, 000 | August 5, 1880. |
| 154 | 1176 | Coast chart No. 54, Long Island to Hunting Island | 1-80, 000 | January 26, 1881. |
| 155 | 1353 | Coast chart No. 55, Hunting Island to Ossabaw Island | 1-80, 000 | June 15, 1881. |
| 156 | 1341 | Coast chart No. 56, Savannah to Sapelo Island | 1-80, 000 | Plate in hand. |
| 157 | 1134 | Coast chart No. 57, Sapelo Island to Amelia Island | 1-80, 000 | February 9, 1881. |
| 166 | 884 | Coast chart No. 66, Florida Reefs, Key Biscayne to Carysfort Reef | 1-80, 000 | June 25, 1881. |
| 167 | 1094 | Coast chart No. 67, Florida Reefs, the Elbow to Matecumbe Key | 1-80, 000 | June 22, 1881. |
| 168 | 1100 | Coast chart No. 68, Florida Reefs, Long Key to Newfound Harbor Key | 1-80, 000 | June 30, 1881. |
| 169 | 1125 | Coast chart No. 69, Florida Reefs, Newfound Harbor Key to Boca Grande Key | 1-80, 000 | June 21,1881. |
| 177 | 1445 | Coast chart No. 77, Tampa Bay, Florida | 1-80, 000 | February 28, 1881. |
| 186 | 1290 | Coast chart No. 86, Choctawhatchee Inlet to Pensacola entrance | 1-80, 000 | Plate in hand. |
| 205 | 1216 | Coast chart No. 105. Galveston Bay to Oyster Bay | 1-80, 000 | February 9, 1881. |
| 206 | 1210 | Coast chart No. 106, Oyster Bay to Matagorda Bay | 1-80, 000 | February 2, 1881. |
| 207 | 1334 | Coast chart No. 107, Matagorda Bay | 1-80, 000 | May 4, 1881. |
| 304*a* | 1203 | Harbor chart, Moose à Bec Reach | 1-40, 000 | June 4, 1881. |
| 291 | 1195 | Harbor chart, Mount Desert, Southwest Harbor, and Somes' Sound | 1-40, 000 | June 1, 1881. |
| 310 | 1354 | Harbor chart, Penobscot Bay | 1-40, 000 | June 1, 1881. |
| 311*a* | 1128 | Harbor chart, Fox Islands Thoroughfare | 1-20, 000 | September 2, 1880. |
| 317 | 1333 | Harbor chart, Winter Harbor | 1-20, 000 | March 19, 1881. |
| 345 | 860 | Harbor chart, Muskeget Harbor | 1-60, 000 | December 15, 1880. |
| 348 | 779 | Harbor chart, Wood's Hole Harbor | 1-20, 000 | June 8, 1881. |
| 353 | 1241 | Harbor chart, Narragansett Bay, upper | 1-40, 000 | February 1, 1881. |
| 353 | 1240 | Harbor chart, Narragansett Bay, lower | 1-40, 000 | August 1, 1880. |
| 358 | 1385 | Harbor chart, Fisher's Island Sound | 1-40, 000 | September 15, 1880. |
| 360 | 1544 | Harbor chart, mouth of Connecticut River | 1-20, 000 | |
| 368 | 179 | Harbor chart, Huntington Bay | 1-30, 000 | March 1, 1881. |
| 553 | 1489 | Harbor chart, Lake Champlain No. 1, Rouse's Point to Cumberland Head | 1-40, 000 | January 3, 1881. |
| 554 | 1501 | Harbor chart, Lake Champlain No. 2, Cumberland Head to Ligonier Point | 1-40, 900 | December 31, 1880. |
| 369 | 1266 | Harbor chart, New York Bay and harbor, lower | 1-40, 000 | June 30, 1881. |
| 369 | 1268 | Harbor chart, New York Bay and harbor, upper | 1-40, 000 | February 4, 1881. |
| 369*a* | 1304 | Harbor chart, New York entrance | 1-40, 000 | February 2, 1881. |
| 370 | 1034 | Harbor chart, Hudson River No. 1, New York to Haverstraw | 1-60, 000 | June 30, 1881. |
| 372 | 954 | Harbor chart, Hudson River No. 3, Poughkeepsie to Troy | 1-40, 000 | June 3, 1881. |
| 374 | 1003 | Harbor chart, Absecon Inlet | 1-20, 000 | July 20, 1880. |
| 376 | 453 | Harbor chart, Delaware and Chesapeake Bays | 1-400, 000 | May 13, 1881. |
| 384 | 1620 | Harbor chart, Patapsco River | 1-60, 000 | January 12, 1881 |
| 386 | 784 | Harbor chart, Patuxent River, lower | 1-60, 000 | June 1, 1881. |
| 387 | 863 | Harbor chart, Patuxent River, Point Judith to Nottingham | 1-30, 000 | June 2, 1881. |
| 388 | 1171 | Harbor chart, Potomac River No. 1, entrance, and up to Piney Point | 1-60, 000 | January 20, 1881. |
| 391 | 1319 | Harbor chart, Potomac River No. 4, Indian Head to Georgetown | 1-40, 000 | June 3, 1881. |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Dates of last corrections and additions. |
|---|---|---|---|---|
| 406 | 851 | Harbor chart, North Landing River | 1–40, 000 | December 2, 1880. |
| 409 | 983 | Harbor chart, mouth of Roanoke River | 1–30, 000 | January 20, 1881. |
| 416 | 1223 | Harbor chart, Hatteras Shoals | 1–120, 000 | June 3, 1881. |
| 417 | 921 | Harbor chart, Hatteras Inlet | 1–20, 000 | October 14, 1880. |
| 419 | 1023 | Harbor chart, Cape Lookout Shoals | 1–80, 000 | March 15, 1881. |
| 421 | 1018 | Harbor chart, Cove Sound and Straits | 1–40, 000 | October 23, 1880. |
| 431 | 1192 | Harbor chart, Charleston Harbor | 1–30, 000 | January 25, 1881. |
| 437 | 1329 | Harbor chart, Whale Branch, inside passage between Coosaw and Broad Rivers | 1–40, 000 | August 25, 1880. |
| 438 | 1233 | Harbor chart, Beaufort River and inside passage between Port Royal and Saint Helena Sound. | 1–40, 000 | October 18, 1880. |
| 440 | 1070 | Harbor chart, Savannah River and Wassaw Sound | 1–40, 000 | February 3, 1881. |
| 441 | 948 | Harbor chart, Ossabaw Sound | 1–30, 000 | October 19, 1880. |
| 453 | 1288 | Harbor chart, Saint Mary's River and Fernandina Harbor | 1–20, 000 | January 19, 1881. |
| 469 | 1170 | Harbor chart, Key West Harbor | 1–50, 000 | March 30, 1880. |
| 474 | 1121 | Harbor chart, Charlotte Harbor | 1–40, 000 | April 13, 1881. |
| 475 | 1138 | Harbor chart, Caloosa Entrance | 1–40, 000 | May 7, 1881. |
| 488 | 699 | Harbor chart, Saint Andrew's Bay | 1–40, 000 | June 8, 1881. |
| 489 | 861 | Harbor chart, Escambia and Santa Maria de Galvaez Bays | 1–30, 000 | June 8, 1881. |
| 490 | 1391 | Harbor chart, entrance to Pensacola Bay | 1–30, 000 | June 20, 1881. |
| 502 | 94 | Harbor chart, Pass Christian Harbor | 1–40, 000 | March 1, 1881. |
| 519 | 332 | Harbor chart, Sabine Pass | 1–40, 000 | June 25, 1881. |
| 601 | 1036 | Sailing chart, California, Oregon, and Washington Territory—Sheet No. 1, San Diego to San Francisco. | 1–1, 200, 000 | February 8, 1881. |
| 602 | 435 | Sailing chart, California, Oregon, and Washington Territory—Sheet No. 2, San Francisco to Umpquah River. | 1–1, 200, 000 | October 12, 1880. |
| 603 | 650 | Sailing chart, California, Oregon, and Washington Territory—Sheet No. 3, Umpquah River to northwest boundary. | 1–1, 200, 000 | January 12, 1881. |
| 700 | 1083 | Sailing chart, northwest coast of America, Sheet No. 1, Cape Flattery to Dixon Entrance | 1–1, 200, 000 | January 31, 1881. |
| 701 | 1132 | Sailing chart, northwest coast of America, Sheet No. 2, Dixon Entrance to Cape Saint Elias | 1–1, 200, 000 | January 5, 1881. |
| 702 | 1133 | Sailing chart, northwest coast of America, Sheet No. 3, Icy Bay to Seven Islands | 1–1, 200, 000 | October 12, 1880. |
| 675 | 1064 | General coast chart, Point Pinos to Bodega Head | 1–200, 000 | March 7, 1881. |
| 612 | 625 | Harbor chart, eastern entrance to Santa Barbara Channel | 1–80, 000 | March 12, 1881. |
| 621 | 818 | Harbor chart, San Francisco Bay entrance | 1–50, 000 | March 12, 1881. |
| 618 | 959 | Harbor chart, Monterey Bay | 1–60, 000 | January 5, 1881. |
| 635 | 1302 | Harber chart, Saint George's Reef and Crescent City | 1–40, 000 | September 15, 1880. |
| 640 | 1245 | Harbor chart, Columbia River No. 1 | 1–40, 000 | August 11, 1880. |
| 650 | 789 | Harbor chart, Port Gamble | 1–20, 000 | October 15, 1880. |
|  |  | ATLANTIC COAST PILOT CHARTS. |  |  |
| ...... | 1560 | Entrance to New York Bay | 1–80, 000 | June 12, 1881. |
| ...... | 1583 | Sandy Hook to Seagirt | 1–80, 000 | June 13, 1881. |
| ...... | 1581 | Seagirt to Barnegat Inlet | 1–80, 000 | June 20, 1881. |
| ...... | 1591 | Barnegat Inlet to Brigantine Inlet | 1–80, 000 | June 13, 1881. |
| ...... | 1592 | New Inlet to Absecon Inlet | 1–80, 000 | June 23, 1881. |
| ...... | 1585 | Absecon Inlet to Leaming's Beach | 1–80, 000 | June 21, 1881. |
| ...... | 1589 | Leaming's Beach to Cape May | 1–80, 000 | June 23, 1881. |
| ...... | 1564 | Delaware Entrance | 1–80, 000 | June 29, 1881. |
| ...... | 893 | Progress sketch, Section 1, northern part | 1–400, 000 | Up to 1877. |
| ...... | 62 | Progress sketch, Section 3, Chesapeake Bay and tributaries | 1–400, 000 | Do. |
| ...... | 451 | Progress sketch, Section 4, coast and sounds of North Carolina | 1–400, 000 | Do. |
| ...... | 1369 | Progress sketch, Section 3, primary triangulation between the Maryland and Georgia base-lines, northern part. | 1–1, 000, 000 | Do. |
| ...... | 1370 | Progress sketch, Sections 4 and 5, primary triangulation between the Maryland and Georgia base-lines, southern part. | 1–1, 000, 000 | Do. |
| ...... | 563 | Progress sketch, Section 5, coast of South Carolina and Georgia | 1–600, 000 | Do. |
| ...... | 1359 | Progress sketch, Section 6, east coast of Florida, Halifax River to Cape Canaveral | 1–200, 000 | Do. |
| ...... | 1368 | Progress sketch, Section XV, geodetic connection of the Atlantic and Pacific coast triangulation, Missouri and Illinois. | 1–400, 000 | Do. |
| ...... | 893 | Progress sketch, Section 1, northern part | 1–400, 000 | Up to 1879. |
| ...... | 1166 | Progress sketch, Section 1, primary triangulation between the Hudson and Saint Croix Rivers | 1–1, 000, 000 | Do. |
| ...... | 57 | Progress sketch, Section 2, northern part | 1–400, 000 | Do. |
| ...... | 58 | Progress sketch, Section S2, southern part | 1–400, 000 | Do. |
| ...... | 62 | Progress sketch, Section 3, Chesapeake Bay and tributaries | 1–400, 000 | Do. |

## APPENDIX No. 5—Continued.

| Catalogue No. | Plate No. | Title of plates. | Scale. | Dates of last corrections and additions. |
|---|---|---|---|---|
| ...... | 451 | Progress sketch, Section 4, coast and sounds of North Carolina | 1-400, 000 | Up to 1879. |
| ...... | 1623 | Progress sketch, Section 3, primary triangulation between the Maryland and Georgia base-lines, northern part. | 1-1, 000, 000 | Do. |
| ...... | 1370 | Progress sketch, Sections 4 and 5, primary triangulation between the Maryland and Georgia base-lines, southern part. | 1-1, 000, 000 | Do. |
| ...... | 563 | Progress sketch, Section 5, coast of South Carolina and Georgia | 1-600, 000 | Do. |
| ...... | 1243 | Progress sketch, Section 6, east coast of Florida, Amelia Island to Halifax River | 1-200, 000 | Do. |
| ...... | 1359 | Progress sketch, Section 6, east coast of Florida, Halifax River to Cape Canaveral | 1-200, 000 | Do. |
| ...... | 1269 | Progress sketch, west coast of Florida, Tampa Bay and vicinity | 1-200, 000 | Do. |
| ...... | 566 | Progress sketch, west coast of Florida, Saint Joseph's Bay to Mobile Bay | 1-600, 000 | Do. |
| ...... | 567 | Progress sketch, Section 8, coast of Alabama, Mississippi, and Louisiana | 1-600, 000 | Do. |
| ...... | 568 | Progress sketch, Section 9, coast of Texas | 1-600, 000 | Do. |
| ...... | 569 | Progress sketch, Section 10, coast of California, lower | 1-600, 000 | Do. |
| ...... | 570 | Progress sketch, Section 10, coast of California, middle | 1-600, 000 | Do. |
| ...... | 1215 | Progress sketch, Section 10, coast of California, upper, and (Section 11) lower coast of Oregon | 1-600, 000 | Do. |
| ...... | 573 | Progress sketch, Section 11, upper coast of Oregon and Washington Territory | 1-600, 000 | Do. |
| ...... | 1368 | Progress sketch, geodetic connection of the Atlantic and Pacific coast triangulation, Missouri and Illinois. | 1-400, 000 | Do. |

# APPENDIX No. 6.

## GENERAL INDEX OF SCIENTIFIC PAPERS, METHODS, AND RESULTS CONTAINED IN THE APPENDICES OF THE ANNUAL REPORTS OF THE UNITED STATES COAST AND GEODETIC SURVEY, FROM 1845 TO 1880 INCLUSIVE.

BY C. H. SINCLAIR, Subassistant.

### KEY TO INDEX.

GEODESY:
- Reconnaissance.
- Base-Lines and Standards of Length.
- Triangulation and Instruments.
- Time.
- Azimuth.
- Latitude.
- Longitude.
- Arc Measures and Local Deflection of Plumb-Line.
- Geographical Positions and Projections.

HYPSOMETRY:
- Spirit-Leveling.
- Trigonometric and Barometric Heights.

SURVEYING:
- Topography.
- Hydrography.

PHYSICAL HYDROGRAPHY:
- Tides, Currents, and Winds.
- Gulf Stream.
- Deep-Sea Soundings and Temperatures.

TERRESTRIAL MAGNETISM.
DRAWING, ENGRAVING, AND ELECTROTYPING.
ASTRONOMY.
MATHEMATICS.
MISCELLANEOUS.

[NOTE.—The pages of the Appendices for 1853 and 1854 are marked with an asterisk (*), to distinguish them from the pages of the Report. The Appendices marked with a dagger (†) have been published in separate form.]

## GEODESY.

### RECONNAISSANCE.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1851 | 31 | 488–494 | FLORIDA COAST RECONNAISSANCE.—F. H. Gerdes.<br>A, description; B, survey; C, tides and currents; D, railroad across the peninsula; E, light-houses and buoys; F, general remarks on Cedar Keys Harbor.—[Sketches 27, 28, and 29.] |
| 1852 | 12 | 87–94 | Extracts from the report of Assistant F. H. Gerdes on a reconnaissance from Suwannee River, Florida, to Delta of Mississippi. |
| 1852 | 18 | 104–107 | Report of Lieut. Commander James Alden, U. S. N., on the reconnaissance from San Francisco to San Diego, including Santa Barbara Islands. |
| 1854 | 20 | *28–*30 | Extracts from the report of F. H. Gerdes on the reconnaissance of the coast of Louisiana in 1854 (Mississippi Delta). |
| 1854 | 21 | *30–*31 | Extracts from a report of W. E. Greenwell on the general features and peculiarities of the coast of Lower Texas, with suggestions in regard to facilities for navigation, from the harbor of the Brazos de Santiago to the mouth of the Rio Grande. |
| 1855 | 25 | 171–176 | FLORIDA KEYS.<br>Survey for the General Land Office, including reports on the general topography and triangulation, on the determination of the shore-line, and reconnaissance of Barnes's Sound, Florida. |
| 1856 | 52 | 286–289 | FLORIDA KEYS.<br>Report of the Superintendent to the Commissioner of the General Land Office on progress made in the survey and marking in quarter-sections. |
| 1857 | 41 | 379–382 | FLORIDA PENINSULA AIR-LINE.<br>Report of a reconnaissance made between Fernandina and Cedar Keys.—By Capt. J. H. Simpson United States Topographical Engineers. |

## GEODESY—Continued.

### RECONNAISSANCE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1857 | 42 | 382–390 | Florida Keys.<br>Superintendent's report to Commissioner of General Land Office on progress made in survey and marking of the Keys. |
| 1857 | 43 | 390–391 | Coast of Santa Barbara Channel.<br>Report of Subassistant W. M. Johnson on its topographical characteristics. |
| 1857 | 44 | 392–395 | Santa Barbara Islands and main.<br>Report on the character and progress of the work.—W. E. Greenwell. |
| 1858 | 34 | 224 | Eastern coast of Florida, south of Saint John's River.<br>Report of Subassistant J. Mechan on local characteristics. |
| 1858 | 35 | 225–227 | Florida Keys.<br>Superintendent's report to Commissioner of General Land Office on progress made in survey and marking of the Keys—Continued. |
| 1859 | 32 | 324–328 | Coast of Texas, embracing the shores of Espiritu Santo, San Antonio, and Aransas Bays.<br>Report on a reconnaissance.—S. A. Gilbert. |
| 1860 | 34 | 356–357 | Corpus Christi Bay and Laguna Madre, Texas.<br>General description of characteristics.—S. A. Gilbert. |
| 1861 | 29 | 263–264 | Coast of Texas above Galveston Bay.<br>Extracts from a descriptive report.—Capt. George Bell, U. S. A. |
| 1873 | †11 | 111–122 | Geographical and hydrographical explorations on the coast of Alaska.—W. H. Dall.<br>[Sketch No. 17.] Islands of Attu, Bouldyr, Kyska, Amchitka, Adakh, Atka, Amlia, Four Craters, Agashagok, Unalashka, Sannakh Reefs; Popoff Strait; current observations; azimuths; positions and magnetic declinations, tables 1 to 16; thermometer, mean for 1873; surface of sea-water; five fathoms below surface; current observations made on board the Yukon during the voyage from San Francisco to Unalashka, May 1873; heights of mountains determined in 1873. |

### BASE-LINES AND STANDARDS OF LENGTH.

| | | | |
|---|---|---|---|
| 1854 | 35 | *103–*108 | Base-measuring apparatus, description of, as used in the Coast Survey.—Lieut. E. B. Hunt, U. S. Engineers.<br>[Sketch 54.] |
| 1855 | 41 | 264–267 | Preliminary base-apparatus.—C. O. Boutelle.<br>[Sketch 53.] |
| 1856 | 60 | 308–310 | Subsidiary base-apparatus.<br>Description of a modification devised for ascertaining the temperature of rods in use.—[Sketch 64.] |
| 1857 | 26 | 302–305 | Epping base, Maine.—A. D. Bache.<br>Notes on the preparation of site, measurement of line, and progress, as compared with other measurements of the Coast Survey.—[Sketch 3.] |
| 1857 | 45 | 395–398 | Base apparatus for measuring subsidiary lines; description.—J. E. Hilgard.<br>[Sketch 69.] |
| 1862 | 26 | 248–255 | Base-measuring apparatus.—J. E. Hilgard.<br>Abstract of experiments for determining the length and expansion by heat of the standard bar, with table of comparisons of standard bar with 6 meters.—[Sketch 49.] |
| 1864 | 14 | 120–144 | Epping base-line.—C. A. Schott.<br>Report on the method of computation and resulting connection with the primary triangulation.—1, general remarks on the method of reduction; 2, instruments and methods of horizontal measures employed in the triangulation near the Epping base; 3, determination of probable error and weight to each direction observed with the 30-inch theodolite; station Howard; abstract of remaining differences; abstract of remaining errors—table; 4, determination of probable error and weight to each angle and direction from observations with a repeating-circle; 5, resulting horizontal angles from the observations at each station, with their probable error: 6, effects upon the horizontal angles of a difference of level between the stations occupied and observed upon; 7, spherical excess of triangles; 8, residuals in the sum of angles of each triangle, and their discussion; 9, final determination of probable errors (and weights) to each direction; 10, relative value of results from the 30-inch and the 10-inch repeating-theodolites; 11, formation of the conditional equation of the nonagon around the Epping base; 12, equation of correlatives and normal equations; 13, resulting correction to the observed directions; 14, complete adjustment of the nonagon and final directions; 15, triangle side-computations; 16, resulting distances from Mount Desert to Humpback; 17, connection of the azimuth-mark with the adjusted directions.—[Errata, 143: 1866, p. 141.] |
| 1865 | 21 | 187–203 | Results of the primary triangulation of the coast of New England, from the northeastern boundary to the vicinity of New York; length and accuracy of the Fire Island base-line; length and accuracy of the Massachusetts base-line; length and accuracy of Epping base-line; geodetic connection of the three primary base-lines in Maine, Massachusetts, and New York, their degree of accordance and resulting accuracy of the primary triangulation intervening; resulting angles and distances of the primary triangulation between the Epping, Massachusetts, and Fire Island base-lines.—[Errata, 198: 1866, p. 141.] |

## GEODESY—Continued.

### BASE-LINES AND STANDARDS OF LENGTH—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1866 | 8 | 49–54 | PRIMARY TRIANGULATION OF THE ATLANTIC COAST.—C. A. Schott.<br>Geodetic connection of the two primary base-lines in New York and Maryland, their degree of accordance and accuracy of the primary triangulation intervening, with the resulting angles and distances as finally adjusted. |
| 1866 | 8 | 140 | Length of the Kent Island base-line.—[Supplement to C. A. Schott's report on primary triangulation of the same year.] |
| 1867 | 7 | 134–137 | COMPARISON OF METERS.—F. A. P. Barnard and H. Tresca.<br>Comparison of an iron meter forwarded to France by the Government of the United States of America; Table I, the United States meter upon the comparator; II, the Conservatoire standard upon the comparator; III, the United States meter upon the comparator; IV, results. |
| 1868 | 7 | 133–139 | Full explanation of the different successive operations connected with the measurement of a subsidiary base-line |
| 1869 | 6 | 105–112 | CONNECTION OF THE PRIMARY BASE-LINES on Kent Island, Md., and on Craney Island, Va., and on the degree of accuracy of the intervening primary and subprimary triangulations.—C. A. Schott.<br>Statistics of conditions; linear discrepancies in the base-lines; degree of accuracy; final correction of directions; adjustment of the subprimary stations; Cape Charles height and north end of measurement; adjustment of the secondary station, Hampton Seminary; table of Atlantic series of primary triangles continued. |
| 1873 | †12 | 123–136 | PEACH-TREE RIDGE BASE, near Atlanta, Ga.—C. A. Schott.<br>Measurement of line in 1872–1873 by C. O. Boutelle [Sketch No. 18]; condition of the apparatus; comparison of the tubes, synopsis of results; table of horizontal distances measured between temporary marks near the monuments in each of the three measures; corrected distances; discrepancies in the three measures; heights above mean half-tide; probable error of computed length; comparison with the accuracy of other base-lines. |
| 1873 | 12 | 132 | DESCRIPTION OF THE COMPENSATION BASE APPARATUS of the United States Coast Survey.—E. B. Hunt.<br>(Reprinted from Appendix No. 35, Coast Survey Report of 1854.) |
|  |  | 136 | SUPPLEMENT.—The "Borda Thermometer" attachment. |
| 1876 | †22 | 402–406 | THE RELATIONS OF THE LAWFUL STANDARDS OF MEASURE of the United States to those of Great Britain.—J. E. Hilgard.<br>Measures of weight, of capacity, of length; relation of yard to meter. Annex I. Measures of length, of surface, of capacity, weights. Annex II. Comparison of yards and meters. |
| 1877 | †12 | 148–181 | COMPARISON OF AMERICAN AND BRITISH STANDARD YARDS.—J. E. Hilgard.<br>1, relation of the lawful standards of measure of the United States to those of Great Britain and France; measures of weight, capacity, length; relation of yard to meter; annex I, II, measure of length, surface, capacity, weights; annex III, comparison of yards and meters; 2, description of the Troughton 86-inch scale; 3, description of British standard yards, bronze No. 11, and iron No. 57.<br>Co-efficient of expansion of the British standard yard bar, bronze No. 11; being a new discussion of the experiments of Sheepshanks and Clarke.—By J. Homer Lane.<br>The relative expansion of bronze 12, and Low Moor iron; for absolute expansion of bronze 12 and brass 2; equations of condition; recapitulation; addendum by O. H. Tittmann; 5, relative lengths of bronze yard No. 11 and iron yard No. 57; experimental comparisons on the dividing machine; comparisons on line and end comparator; on the beam compass comparator; comparisons of British bronze yard No. 11 with the Imperial yard and other standards of Great Britain; 1, comparisons with standards of the Dominion of Canada; abstract of comparisons between No. 11 and No. 16; between No. 11 and Dominion Standard A; between Dominion Standard A and No. 16; comparisons with the Imperial yard and other standards of the Standard Office, Westminster, London; rates of expansion; results of comparison of bronze No. 11 (U. S.) with bronze No. 1 (Imperial yard); of No. 11 with bronze No. 6 (Generator); of No. 11 with cast iron B and C; tabulation of results of comparison between No. 11 and foreign standards; 7, comparison of the Troughton scale with the British bronze standard No. 11; 8, concluding statement. |
| 1880 | †17 | 341–344 | BASE-APPARATUS.—J. E. Hilgard.<br>An account of a perfected form of the contact-slide base-apparatus used in the Coast and Geodetic Survey.—[Sketch 82, Figs. 1 to 8.] |

### TRIANGULATION AND INSTRUMENTS.

|  |  |  |  |
|---|---|---|---|
| 1855 | 57 | 361–363 | BOUTELLE'S TRIPOD AND SCAFFOLD.—C. O. Boutelle.<br>Description of, as constructed and used by him at the stations of the primary triangulation in Section V.—[Sketch 52.] |
| 1855 | 58 | 363–364 | FARLEY'S SIGNAL.—J. Farley.<br>Description and drawing of a convenient signal for observing on secondary stations.—[Sketch 52.] |
| 1855 | 59 | 364 | SANDS'S HELIOTROPE.—B. F. Sands.<br>Description and drawing of a convenient signal for observing on secondary stations. [Sketch 55. |
| 1856 | 56 | 291–292 | MISSISSIPPI SOUND.—J. E. Hilgard.<br>Details of the work of triangulation; signals and station-marks. |

## GEODESY—Continued.

### TRIANGULATION AND INSTRUMENTS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1856 | 61 | 310-316 | THEODOLITE-TEST.—J. E. Hilgard.<br>Examination and trials made of a 10-inch theodolite, applicable to the testing of instruments of like construction.—Table I, readings of every 10 degrees on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III, residual errors of graduation and readings; figure of pivots. |
| 1860 | 35 | 357-361 | REPEATING-THEODOLITE.<br>Supplement to the method of testing (described in the preceding paper).—Table I, readings of every 10 degrees on the circle, and determination of angular distance of verniers; II, determination of eccentricity; III residual errors of graduation and readings. |
| 1867 | 9 | 140-144 | RAILWAYS, on the use of, for geodetic surveys.—J. E. Hilgard.<br>Wheel-records; linear measurement; rectification of curves; reduction of the measured lines and angles to a simpler system.—[Sketch 26.] |
| 1867 | 10 | 145 | REFLECTOR.—J. E. Hilgard.<br>Description of a new form of geodetic signals.—[Sketch 26.] |
| 1868 | †7 | 109-139 | MEMORANDA RELATING TO THE FIELD-WORK OF A SECONDARY TRIANGULATION.—R. D. Cutts.<br>Selection of stations; names of stations; signals; tripods and scaffolds; underground station marks; surface station-marks; observations and records; number of observations; limit of error; probable error; reduction to center; correction for phase; correction for eccentricity; spherical excess; distribution of error; trigonometrical leveling; co-efficient of refraction; three-point problem; rectangular co-ordinates; measurements of subsidiary base-lines; records, duplicates, and computations. |
| 1868 | 8 | 140-146 | METHOD OF ADJUSTMENT OF THE SECONDARY TRIANGULATION OF LONG ISLAND SOUND.—C. A. Schott.<br>Example of reduction of angular measure of Shelter Island; final computation and proof of correctness. |
| 1871 | 15 | 185-188 | ADAPTATION OF TRIANGULATION to the various conditions of configuration and character of the surface of country and other causes.—C. A. Schott. |
| 1873 | †13 | 137 | INTERVISIBILITY OF STATIONS.—J. E. Hilgard. |
| 1874 | †15 | 153 | IMPROVED CLAMP FOR TELESCOPE OF THE THEODOLITE.—George Davidson. |
| 1875 | †17 | 279-292 | METHOD OF CLOSING A CIRCUIT OF TRIANGULATION under certain conditions.—C. A. Schott, M. A. Doolittle. Illustrations. |
| 1876 | †20 | 391-399 | ADAPTATION OF TRIANGULATION to various conditions depending on the configuration or orthographic character of a country, and in the degree of accuracy aimed at, with due consideration of the time and means available; also notes on the method of observing horizontal angles and directions in geodetic surveys.—C. A. Schott.<br>[Reprinted, with additions, from Report for 1871, Appendix No. 15.] |
| 1877 | †11 | 114-147 | AN EXAMINATION of three new 20-inch theodolites.—J. E. Hilgard.<br>Examination of No. 113; of Nos. 114 and 115; subdivisions on limb of No. 114; of No. 115; example of record; graphic projection of $\varepsilon \sin (r-\rho)$; examination of limb of No. 114; Tables I, II, III (first set); Tables I, II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limb of No. 113; Tables I, II, III (first set); Tables I, II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limb of No. 115; Tables I, II, III (first set); Tables I, II, III (second set); Tables I, II, III (third set); residual errors of graduation and reading; examination of limbs of 20-inch theodolites with reference to periodicity of errors within 5°; specimen of record (No. 114); mean value of 5′ spaces; of degrees. |
| 1877 | †13 | 182 | IMPROVED OPEN VERTICAL CLAMP for telescopes of theodolites and meridian instruments.—George Davidson. |
| 1878 | †8 | 92-118 | PRIMARY TRIANGULATION between the Maryland and Georgia base-lines.—C. A. Schott.<br>Arrangement of errors in closing triangles, in tabular form; average probable error. Paper 1. Adjusted primary triangles between Kent Island, Md., and Atlanta, Ga. 2. Estimation of the probable accuracy of a triangulation or approximate determination of the average probable error of the adjusted differences. 3. Paper by M. H. Doolittle; I, general method of solution of normal equations; II, addition of new equations; III, order of solution; IV, selection of angle-equations; V, treatment of small angles; example. |
| 1880 | †8 | 96-109 | GEODETIC NIGHT-SIGNALS.—C. O. Boutelle.<br>Considerations; different kind of lights; conditions of the problem; experiments in North and South Carolina; operations at Sugar Loaf Mountain in 1879; method of observing; comparison of day and night observations; additional expense in using night-signals; offsets to the expense; conclusions; sketches Nos. 36, 37. |

### TIME.

| | | | |
|---|---|---|---|
| 1854 | 39 | 121 | DISCUSSION OF PROBABLE ERROR OF OBSERVATION with a Würdemann 26-inch portable transit; from observations by G. Davidson in 1853. [Report of 1866, Sketch 29.]—J. E. Hilgard. |
| 1865 | 15 | 152-154 | REPORT AND TABLES on the declinations of standard time-stars.—B. A. Gould. |
| 1865 | 16 | 155-159 | REPORT AND TABLES on the positions and proper motions of the four polar stars.—B. A. Gould. |
| 1866 | †9 | 55-71 | THE TRANSIT-INSTRUMENT, description, use, adjustment, and method of observation.—C. A. Schott. |
| 1867 | †8 | 138-139 | MERIDIAN AND EQUAL-ALTITUDE INSTRUMENTS.—George Davidson.—[Sketch 28.] |
| 1868 | †10 | 154-157 | ADDENDA TO APPENDIX NO. 9, Coast Survey Report for 1866, on the determination of time by means of the transit-instrument.—C. A. Schott. |

## GEODESY—Continued.

### TIME—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1869 | 12 | 226–232 | ON THE USE OF THE ZENITH-TELESCOPE for observations of time, with an example of observation.—J. E. Hilgard. |
| 1872 | †12 | 222–226 | DETERMINATION OF WEIGHTS to be given to observations for determining time with portable transit-instrument, recorded by the chronographic method.—C. A. Schott.<br>Relative weights to transits depending on the star's declination; relative weights to incomplete transit observations; reduction of observations for time. |
| 1872 | 18 | 266 | IMPROVEMENT ON THE HIPP CHRONOGRAPH.—William Eimbeck. |
| 1874 | †17 | 156–159 | TWO FORMS OF PORTABLE PERSONAL EQUATION APPARATUS.—J. E. Hilgard.<br>Examples of observations; observations for absolute personal equation; diagrams. |
| 1875 | †15 | 249–250 | DESCRIPTION OF AN APPARATUS for recording the mean of the times of a set of observations. [Diagram.]—C. S. Peirce. |
| 1877 | †13 | 182–183 | IMPROVED OPEN VERTICAL CLAMP for telescopes of theodolites and meridian instruments.—George Davidson. |
| 1879 | †7 | 103–109 | DESCRIPTION OF A NEW MERIDIAN INSTRUMENT.—George Davidson.<br>See Appendix No. 8, Report of 1867, for first printed description. |
| 1880 | †14 | 205–227 | DETERMINATION OF TIME by means of the transit instrument. [Four plates.]—C. A. Schott.<br>General remarks; description; adjustment; method of observation; equatorial intervals of threads; incomplete transits; corrections for rate of chronometer, for inclination, for inequality of pivots, for collimation, for deviation, for diurnal aberration; personal equation; chronometer correction; reduction of observations by least squares; probable error; example; weights; preparation for observing transits; example of record and computation of inequality of pivots; specimen of record for value of level by level-trier; tabulation of factors; table of factors for reduction of transit observations. |

### AZIMUTH.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1856 | 27 | 208–209 | AZIMUTH.—J. E. Hilgard.<br>Method of using the transit-instrument for azimuth-observations; residual errors of graduation and readings. |
| 1866 | 11 | 86–99 | ASTRONOMICAL AZIMUTH.—C. A. Schott.<br>1, principal methods; 2, astronomical azimuth; 3, geodetic azimuth; 4, primary and secondary azimuths; 5, time; 6, instruments used; 7, azimuth-marks; 8, errors eliminated; 9, circumpolar stars used; 10, high stars; 11, sets of observations; 12, method of recording and reducing; 13, observations of a close circumpolar star near its elongation; 14, at any hour-angle; 15, computation by fundamental trigonometrical formula; 16, by Napier's analogies; 17, by a development into a series; 18, at equal intervals before and after culmination; 19, observation of sun for azimuth; 20, examples of records and reductions to articles 11, 13, 14, 15, 17, 18, and 19.—[Sketches 26 and 27.] |
| 1868 | 10 | 157–165 | [Supplement, 1868, p. 157.—Specimen-table of local times of elongations and culminations of four circumpolar stars for 1873, latitude 40°, longitude 6*h.* west of Greenwich; correction for altered dates and latitudes ]<br>[Supplement, p. 158.—In vertical of star; example of record and reduction; micrometer-values; deduction of azimuth.]<br>[Supplement, p. 160.—(*a*,) near culmination; example of record and computation; eye-piece micrometer, values determined and applied to level-correction; (*b*,) pivot-micrometer, ditto, with example and record of reduction; single micrometer-turn, ditto; discussion of set of four stars; centering of instrument for connection with triangulations.] |
| 1870 | 17 | 178–179 | CHANGES OF ELEVATION AND AZIMUTH caused by the action of the sun at station Dominguez, Cal.—George Davidson. |
| 1870 | 22 | 226–227 | AZIMUTH AND APPARENT ALTITUDE OF POLARIS.—George Davidson. |
| 1880 | †14 | 263–280 | ASTRONOMICAL AZIMUTH.—C. A. Schott.<br>[Four plates ] 1, general remarks; 2, instruments; 3, general considerations; 4, methods; 5, observations of a close circumpolar star near elongation; 5*b*, observations with the transit in the vertical of a close circumpolar star, near its elongation; 6, at any hour-angle; 7, computation by fundamental formula; 8, by Napier's analogies; 9, by development into series; 10, at equal intervals before and after culmination; 10*b*, near culmination with eye-piece micrometer, corrections; 10*c*, with pivot micrometer; 11, observations of sun for azimuth; 12, examples of record and reduction, to Arts. 5, 5*b*, 6 and 7, 9, 10, 10*b*; line of collimations by reversal on star; examples to articles 10*c*, 11; 12, table of local time of elongation and culmination of four circumpolar stars, for 1885, lat. 40°, long. 6*h.* west of Greenwich. |

### LATITUDE.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1855 | 44 | 276–278 | Description of Würdemann's zenith-telescope of 1855, used at Dixmont, Me.—G. W. Dean. |
| 1857 | 31 | 324–334 | LATITUDE.—On the method of determination with the zenith-telescope.—C. A. Schott.<br>Principle of the method; determination of value of micrometer—examples; determination of value of level—example; correction for refraction—example; reduction to meridian—tables; selection of stars; sources of error in the determination of the value of micrometer; method of correcting value from the latitude observations themselves; discussion of the results of observation—example. |

## GEODESY—Continued.

### LATITUDE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1858 | 20 | 184–186 | Personal equation.—A. D. Bache.<br>On the use of the zenith-telescope for determining latitude by Talcott's method—table showing results of observations for personal equation. |
| 1865 | 17 | 160–165 | Report on the latitude of Cloverdon station in Cambridge.—B. A. Gould.<br>Micrometer-values; reduction of star-observations—tables; discrepancies with uncorrected catalogue-places—table; resultant mean places of stars, &c.—table; deduced places for Cloverdon station—table; mean error; other determinations. |
| 1866 | 10 | 72–85 | Latitude by the zenith-telescope.—C. A. Schott.<br>1, general remarks on Talcott's method; 2, modification of instrument; 3, description; 4, adjustment; 5, selection of stars for observation; 6, directions for observing; 7, off the meridian; 8, general expression for the latitude; 9, determination of the value of a division of micrometer; 10, of level; 11, correction for differential refraction; 12, reduction to the meridian; 13, record of the observations; 14, reduction of the observations; 15, discussion of the results; 16, combination of the results by weight.—Examples to articles 9, 10, 13, and 14.—[Sketch 28.] |
| 1867 | 8 | 138–139 | Meridian and equal-altitude instruments.—George Davidson.—[Sketch 28]. |
| 1873 | †14 | 138 | List of stars for latitude observations. |
| 1876 | †7 | 83 | A catalogue of stars for latitude observations. |
| 1877 | †13 | 182–183 | Improved open vertical clamp for telescopes of theodolites and meridian instruments.—George Davidson. |
| 1879 | †7 | 103–109 | Description of a new meridian instrument.—George Davidson.<br>See Appendix No. 8, Report of 1867, for first printed description. |
| 1880 | †14 | 245–259 | Latitude determination by means of the zenith telescope.—C. A. Schott.<br>1, general remarks on Talcott's method; 2, modification of instrument; 3, description; 4, adjustment; 5, selection, of stars; 6, directions for observing; 7, bisection of stars off the meridian; 8, general expression for latitude; 9, determination of value of micrometer; 10, determination of value of level; 11, differential refraction; 12, reduction to the meridian; 13, form of record; 14, of reduction; 15, discussion of results; 16, combination of results by weights. Examples to articles 9, 10, 13, and 14. |

### LONGITUDE.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1846 | 10 | 71–72 | Differences of longitude of Philadelphia and Greenwich, by reduction of observations at Cambridge, Mass.—S. C. Walker. |
| 1846 | 11 | 72–74 | Differences of longitude by telegraph.—S. C. Walker.<br>Correction for personal equation. |
| 1848 | 4 | 78–83 | Recapitulation of results for personal equation, 1844–1848.—S. C. Walker. |
| 1848 | 19 | 112–118 | Longitude computations.—S. C. Walker. |
| 1849 | 5 | 72–78 | Mechanical record of astronomical observations.—Professor O. M. Mitchell. |
|  |  | 74 | His revolving disk; arrangement for recording differences of declinations. |
| 1850 | 6 | 79 | Differences of longitude between Cambridge and Liverpool Observatories.—W. C. Bond. |
| 1850 | 13 | 85–89 | Telegraphic Operations and Computations.—S. C. Walker.<br>I, Experiments for galvanic wave-time between Washington and Saint Louis; II, attempted experiments on wave-time through different conductors; III, experiments with the chemical telegraph line; IV, progress of the researches on the velocity of the galvanic current; the Bond spring-governor. |
| 1851 | 18 | 462–463 | Telegraphic arrangement to determine the difference of longitude between Cambridge and Halifax.—S. C. Walker. |
| 1851 | 25 | 476–479 | Measures of wave-time, made from 1849 to 1851.—S. C. Walker.<br>Specifications and tables of results. |
| 1851 | 26 | 480–481 | Longitude of Harvard Observatory.—S. C. Walker.<br>By moon-culminations, eclipses, transits, occultations, and telegraph. |
| 1853 | 31 | *84 | On longitude from moon-culminations.—Benjamin Peirce.<br>On the determination of longitude from observations of moon-culminations; standard probable error of observation of interpolated lunar transits; constant errors of epoch and periodical one of half-lunations. |
| 1853 | 32 | *84–*86 | On moon-culmination observed by the "American method," with remarks on the performance of Bond's spring-governor.—W. C. Bond.<br>Comparison of records made by two spring-governors differing one-tenth of a second in time of pendular vibration; table of star-transits; amount of probable errors |
| 1853 | 33 | *86–*88 | Telegraphic longitude of Charleston, S. C.—B. A. Gould.<br>Results of observations for the determination of difference of longitude by telegraph between Seaton station (Washington, D. C.) and Charleston, S. C. |
| 1853 |  | *88–*89 | Cambridge and Liverpool chronometer-expeditions in 1849, 1850, and 1851.—G. P. Bond.<br>Computations of results for determining difference of longitude. |

## GEODESY—Continued.

### LONGITUDE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1854 | 36 | 108–120 | Longitude by moon-culminations.—Benjamin Peirce.<br>General considerations; constant errors and personal equations; correction of the lunar ephemeris; standard probable error of observation of a lunar transit; limit of accuracy attainable; longitude of the National Observatory, Washington, D. C.; three forms of correcting lunar ephemeris and the modes of computation.—[Errata, 112, 113, 114, 115, 117: 1855, p. xix.] |
| 1854 | 37 | *120 | Moon-culminations.—W. C. Bond.<br>Observed by the American method; chronometric longitude of Cambridge and probable error. |
| 1854 | 38 | *120 | Moon-culminations.—E. O. Kendall.<br>Observed at High School observatory, Philadelphia. |
| 1854 | 39 | 121 | Discussion of probable error of observation with a Würdemann 26-inch portable transit; from observations by G. Davidson in 1853. [Report of 1866, Sketch 29.]—J. E. Hilgard. |
| 1854 | 41 | *123–*131 | Telegraphic longitude.—B. A. Gould.<br>On telegraphic observations for the difference of longitude between Raleigh, N. C., and Columbia, S. C. |
| 1854 | 42 | *138–*142 | Chronometric longitude-expeditions (Cambridge-Liverpool).—G. P. Bond.<br>Results of the expeditions of 1849, 1850, and 1851, and on the method of computation.—[Errata, 140: 1855, p. xix.] |
| 1855 | 42 | 267–274 | Longitudes.—Report on the method of determining longitudes by occultations of the Pleiades.—Benjamin Peirce.<br>[Errata, 268, 269, 270, 272, 273: 1855, p. xviii.] |
| 1855 | 43 | 275–276 | Chronometric longitudes.—W. C. Bond.<br>On moon-culminations observed by him, and the chronometric expedition for determining the longitude-difference between Cambridge, Mass., and Liverpool, England.—[Errata, 275: 1855, p. xviii.] |
| 1855 | 46 | 286–295 | Telegraphic longitudes.—B. A. Gould.<br>Report on telegraphic operations for difference of longitude between Columbia, S. C., and Macon, Ga.; programme of telegraphic campaign; for instrumental corrections and longitude-reductions; battery-memoranda; to put up Kessel's clock.—[Errata, 288: 1855, p. xviii.] |
| 1856 | 20 | 163–166 | Telegraphic longitudes.—B. A. Gould.<br>Operations for difference of longitude between Wilmington, N. C., and Montgomery, Ala., with list of stars for observation. |
| 1856 | 21 | 167–181 | Telegraphic method.—G. W. Dean.<br>Details of the method used in the Coast Survey for telegraphic-determinations of difference of longitude; transit-instrument; astronomical clock; chronographic register; batteries; list of stars arranged from the British Association Catalogue for determining the difference of longitude between Macon, Ga., and Montgomery, Ala., March, 1856; exchange of star-signals; reading off the chronographic sheets; example of reduction; observations for determining the inequality of the pivots of Coast Survey transit No. 8; personal equations.—[Sketch 66.]—[Errata, 169–170: 1856, p. xx.] |
| 1856 | 22 | 181 | Chronometric and astronomical longitudes.—W. C. Bond.<br>On longitude-computations and occultations observed; lunar-spot transits. |
| 1856 | 23 | 182–191 | Chronometric results.—G. P. Bond.<br>Results of the chronometric expeditions of 1849, 1850, 1851, and 1855 for difference of longitude between Cambridge, Mass., and Liverpool, England; table of longitudes by voyages of 1855. |
| 1856 | 24 | 191–197 | Pleiades.—Benjamin Peirce.<br>On the determination of longitude by occultations; formulas for the correction of the co-ordinates of the stars; table for 1840; table of logarithms for $h$ and $k$ for the principal observatories. |
| 1856 | 25 | 198–203 | Lunar-spot transits.—C. H. F. Peters.<br>On the substitution of lunar spots for the moon's limb in observing culminations. |
| 1856 | 26 | 203–208 | Occultations on the western coast.—G. Davidson.<br>Observations made at Port Townsend, Washington Territory, April and May, 1856; tables and remarks. |
| 1857 | 27 | 305–310 | Telegraphic longitudes.—On the progress made in the different campaigns.—B. A. Gould.<br>List of time-stars adopted; difficulties and discrepancies of transmission for signals between Wilmington, N. C., and Columbia, S. C. |
| 1857 | 28 | 310–311 | Moon-culminations.—W. C. Bond.<br>On the number observed during the year at Cambridge, co-operative with those on the Pacific side; star-occultation photographs; connection with Quebec. |
| 1857 | 29 | 311–314 | Longitude-methods.—Benjamin Peirce.<br>On the relative precision of determinations by occultations and solar eclipses; upon the use of the solar eclipses; upon the occultations of the Pleiades. |
| 1857 | 30 | 314–324 | Chronometric determination of the difference of longitude between Savannah, Ga., and Fernandina, Fla., and discussion of the method.—A. D. Bache and C. A. Schott.<br>Chronometers used; personal equation: temperature-compensation; chronometer-comparisons—table; stationary and traveling rates—tables of comparison and discussion. |

## GEODESY—Continued.

### LONGITUDE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1858 | 21 | 186–189 | Longitudes.—Method of computing from moon-culminations; notes on observations of moon-culminations; forms and example. |
| 1858 | 23 | 190 | Moon-culminations, etc.—O. M. Mitchel.<br>Number of observations made by him for the Coast Survey. |
| 1859 | 21 | 278 | Moon-culminations.—O. M. Mitchel.<br>Observations made for the Coast Survey at the Cincinnati Observatory for longitude purposes. |
| 1861 | 16 | 182–195 | Longitude.—Benjamin Peirce.<br>Discussion of observations of the solar eclipse of July, 1851; observations of the total phase; European observations, of which the beginning and the end, both observed at the same place, have been admitted into the computation; American observations; method of computation. |
| 1861 | 17 | 196–221 | Longitude.—Benjamin Peirce.<br>Report on the determination of longitude by occultations of the Pleiades, with an example showing the mode of computation; Greenwich, Cambridge (England), Ashurst, Washington City, Philadelphia, and Boston observatories computed; solution of the equations for the correlation of the moon's place and of the longitude. |
| 1861 | 18 | 221–232 | Longitude of Albany, N. Y.—B. A. Gould.<br>Abstract of a report on the determination by telegraph of the difference of longitude between New York City and Albany; table of instrumental corrections; collimation and azimuth-correction, and hourly clock-rate; personal equations; comparative table of clock-values gained at opposite stations. |
| 1862 | 12 | 155–156 | Longitude of America from Europe.—Benjamin Peirce.<br>On the result from occultation of the Pleiades. |
| 1862 | 13 | 157–158 | Lunar tables used in reducing observations of the Pleiades for longitude.—Benjamin Peirce.<br>On their progressive improvements. |
| 1862 | 14 | 158–160 | Longitudes in Maine, Alabama, and Florida.—B. A. Gould.<br>On progress in computing results from telegraphic observations. |
| 1863 | 17 | 146–154 | Occultations of the Pleiades in 1841–'42.—Benjamin Peirce.<br>On computations for longitude, Nos. I, II, and V; records of Edinburgh, Washington, and Cambridge observations; ephemeris; stereographic co-ordinates of the moon referred to Alcyon; equations for the correction of the moon's place and of the longitude; solutions. |
| 1863 | 18 | 154–156 | Longitude.—B. A. Gould<br>On computations connected with the telegraphic method. |
| 1863 | 23 | 205 | Induction-time in relay-magnets.—G. W. Dean.<br>Report on experiments made to determine their relative power. |
| 1864 | 11 | 114 | Longitude.—Benjamin Peirce.<br>On the method of determining longitudes by occultations of the Pleiades. |
| 1864 | 12 | 115–116 | On results by telegraphic method.—B. A. Gould. |
| 1864 | 20 | 211–220 | Eduction-time of relay-magnets, deduced from experiments.—G. W. Dean. |
| 1865 | 12 | 138–146 | Report on the progress of determining longitude from occultations of the Pleiades, continued from previous reports.—Benjamin Peirce.<br>Values of $\Sigma_2$—*p* for 1838–'42 and 1857–'61. |
| 1865 | 13 | 146–149 | Method of determining longitude from the occultations of the Pleiades, continued from previous reports.—Benjamin Peirce.<br>Corrections of lunar semi-diameter, mean place, ellipticity of orbit, longitude of perihelion, coefficient of annual parallax, and longitude of Europe and America; example. |
| 1865 | 14 | 150–151 | Report on the results of determining longitude by telegraphic method.—B. A. Gould. |
| 1866 | 9 | 55–71 | The transit instrument, description, use, adjustment, and method of observation.—C. A. Schott. |
| 1866 | 12 | 99–100 | Longitude.—[From Report for 1846.]—S. C. Walker.<br>Difference of longitude between Philadelphia and Greenwich by reduction of Cambridge (Mass.) observations. |
| 1866 | 13 | 100–102 | Longitude.—[Report for 1846.]—S. C. Walker. |
| 1866 | 14 | 102–105 | Longitude.—[From Report for 1848.]—S. C. Walker.<br>Difference of longitude between New York, Cambridge, and Greenwich. |
| 1866 | 15 | 106–108 | Longitudes.—[From Report for 1850.]—S. C. Walker.<br>1, Experiments for galvanic-wave time between Washington, D. C., and Saint Louis, Mo.; 2, attempted experiments on wave-time through different conductors; 3, experiments with the chemical-telegraph line; 4, progress of the researches on the velocity of the galvanic current. |
| 1866 | 16 | 109–111 | Galvanic-wave time.—[From Report for 1851.]—S. C. Walker.<br>On measurements from 1849 to 1851, with tables. |
| 1866 | 17 | 111–112 | Longitudes.—[From Report for 1851.]—S. C. Walker.<br>Harvard Observatory, west of Greenwich; by moon, eclipses, transits, and occultations; result. |

## GEODESY—Continued.

### LONGITUDE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1867 | 6 | 57–133 | LONGITUDE, TRANSATLANTIC.—B. A. Gould.<br>1, Origin of the Coast Survey expedition in 1866; 2, previous determinations of transatlantic longitudes from eclipses and occultations, from moon-culminations; from chronometers transported from Boston to Liverpool; 3, history of the expedition; programme of transatlantic-longitude campaign; 4, observations at Valencia; table of equatorial intervals; table of observations, October 25 to November 16, 1866; 5, observations at Newfoundland, October 25 to December 16, 1866; 6, observations at Calais, December 11 to 18, 1866; 7, longitude-signals between Foilhommerum and Heart's Content; clock-corrections; transatlantic longitude and transmission-time, October 25 to November 9, 1866; 8, longitude-signals between Heart's Content and Calais; tables of Newfoundland and Calais signals; tables of longitude and times of transmission; 9, personal error in noting signals; 10, personal equation determining time; 11, final results for longitude; 12, velocity of transmission; cables of 1860 and 1865; tables of comparison. |
| 1867 | 8 | 138–139 | MERIDIAN AND EQUAL-ALTITUDE INSTRUMENTS.—George Davidson.—[Sketch 28.] |
| 1868 | 10 | 154–157 | ADDENDA TO APPENDIX No. 9, COAST SURVEY REPORT FOR 1866, on the determination of time by means of the transit instrument.—C. A. Schott. |
| 1869 | 12 | 226–232 | ON THE USE OF THE ZENITH-TELESCOPE FOR OBSERVATIÓNS OF TIME, with an example of observation.—J. E. Hilgard. |
| 1870 | †12 | 100 | RESULTS OF THE TELEGRAPHIC determination of the longitude of San Francisco, Cal. |
| 1870 | †13 | 101–106 | ABSTRACTS OF RESULTS FOR DIFFERENCE OF LONGITUDE between Harvard Observatory, Massachusetts, the Coast Survey station Seaton, and the Naval Observatory, Washington, D. C., by Prof. Joseph Winlock, of Harvard Observatory, and Commodore B. F. Sands, U. S. N. |
| 1872 | †13 | 227–234 | PRELIMINARY REPORT ON THE DETERMINATION OF TRANSATLANTIC LONGITUDES.—J. E. Hilgard.<br>Brest, Greenwich, Paris; results of observation for personal equation; longitudes; Brest–Greenwich, Brest–Paris, Greenwich–Paris; Brest–St. Pierre–Cambridge; Harvard Observatory–Greenwich; Washington–Greenwich; Washington–Paris. |
| 1874 | †18 | 163–247 | TRANSATLANTIC LONGITUDES.—J. E. Hilgard.<br>Final report on the determination of 1872 with a review of previous determinations.<br>Part I. Section I, Cambridge; II, St. Pierre; III, Brest; IV, Paris, Greenwich; V, Cambridge–St. Pierre; VI, St. Pierre–Brest; programme for cable-exchanges; VII, personal error in noting cable time-signals; VIII, wave time of cable-signals; IX, Brest–Paris and Brest–Greenwich; X, personal equation, Blake–Folain; XI, personal equation, Blake–Greenwich standard observer, and longitude Greenwich–Paris; XII, personal equation of Coast Survey observers; XIII, flexure of transit axis; XIV, final discussion of the results for longitude differences, Brest, Greenwich, Paris; XV, final combination of the longitude differences deduced from the observations of 1872, 1870, and 1866; finally adopted longitudes from observations of 1866, 1870, and 1872. |
| | | 182 | Part II. Reduction of the observations made for the transatlantic longitude determination of 1872; computation of observations for clock and instrumental corrections at Cambridge, Mass., 1872; Cambridge clock-corrections, from stars of less than 65° N. declination; computation of observations for clock and instrumental correction at St. Pierre, Miquelon, 1872; St. Pierre clock-corrections, from stars of less than 65° N. declination; adopted clock-corrections, Cambridge and St. Pierre at the epochs of exchanging longitude signals; table of such clock-corrections and rates at St. Pierre as relate to the longitude determination with Brest; computation of observations for clock and instrumental corrections at Brest, Paris, and Greenwich; adopted chronometer corrections from all stars south of 60° N. declination; errors and rates of the sidereal standard clock of the Royal Observatory at Greenwich, connected with the longitude differences Greenwich–Brest and Greenwich–Paris; computation of observations for clock and instrumental corrections of the National Observatory at Paris, France, relating to the differences of longitude, Paris–Brest and Paris–Greenwich; observations for inclination of axis of the Gambey meridian-transit; azimuths of the meridian mark; observations on $\alpha$, $\delta$, and $\lambda$ Ursæ Minoris; coefficients employed in the reduction of the observations; observations made with the Gambey meridian-transit for difference of longitude Paris–Brest; clock corrections and hourly rates at Paris; observations with the Gambey meridian-transit and the Morse-Digney chronograph for difference of personal equation of Blake–Folain; clock-corrections and hourly rates at Paris; observations with the Gambey meridian transit for difference of longitude Paris–Greenwich; clock-corrections and hourly rates at Paris; results of telegraphic time-signals exchanged between Cambridge and St. Pierre; between St. Pierre and Brest; between Brest and Paris; between Brest and Greenwich; between Greenwich (Coast Survey transit) and Paris; personal error in noting cable time-signals at St. Pierre; at Brest; difference of personal equation of Folain and Blake; Criswick and Blake; personal equation; Goodfellow, Blake, and Smith; observations for personal equation at Cambridge, Mass., October and November, 1872; results. [Errata pp. 163, 164, 167, 168, 169, 172, 173, 177, 178, 180, 207, 237, 242.] |

## GEODESY—Continued.

### LONGITUDE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1875 | 9 | 139–155 | Telegraphic longitude of Key West.—C. A. Schott.<br>Introduction; description of observing-stations and of instrumental outfit; relative personal equations; equatorial interval of wires of transit-circle; adopted mean places in right ascension of stars observed at Washington and Key West; probable error of clock-corrections; eduction of transits for clock-corrections, Washington; conditional and normal equations; synopsis of results for correction and rate of clock; reduction of transits for chronometer-corrections, Key West; normal equations for azimuth and chronometer-corrections; synopsis of results for correction and rate of chronometers; telegraphic connection and exchange of time-signals; telegraphic difference of longitude Washington–Key West; resulting longitude of Key West and of light-houses in its vicinity. |
| 1880 | †6 | 81–92 | Telegraphic longitudes.—C. A. Schott.<br>Report on the results of telegraphic longitudes determined by the Coast and Geodetic Survey up to the present time, and preliminary adjustment by least squares; two groups; specimen of the first group; Atlanta and Washington; results for difference of longitude; review of the telegraphic longitude work; published results; method of combining results; table of results of differences of longitude; table of results determining subordinate stations; combination and adjustment of observed differences of longitude; diagram No. 33; conditional equations; resulting adjusted longitudes (west of Greenwich). |
| 1880 | †7 | 93–95 | Telegraphic longitudes.—Edwin Smith.<br>Explanation of apparatus used for observation; description; cases 1 to 5; adjustments; interchange of signals; diagrams Nos. 34 and 35. |
| 1880 | †14 | 231–241 | Determination of longitude by means of the electric telegraph (two plates).—C. A. Schott.<br>1, Telegraphic determination of longitude; 2, personal equation; specimen of record of results for difference of longitude; variability in personal equation; 3, weights to transit-observations recorded on the chronograph; weights depending on the star's declination; weights to incomplete transits; reduction of observations for time; 4, disposition of telegraphic instruments in the observatory; arrangements I to VI; 5, concluding remarks. |

### ARC MEASURES AND LOCAL DEFLECTION OF THE PLUMB-LINE.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1868 | 9 | 147–153 | Results of the measurement of an arc of the meridian.—C. A. Schott.<br>Length of the arc by four methods; accuracy of the preceding results; table and diagram; determination of the astronomical latitudes; recapitulation of results. |
| 1869 | 7 | 113–115 | Local deflections of the zenith in the vicinity of Washington City.—C. A. Schott. |
| 1876 | †15 | 202–337 | Measurements of gravity at initial stations in America and Europe.—C. S. Peirce.<br>Stations Geneva, Paris, Berlin, Kew, Hoboken; instrument; diagram; observations of the duration of an oscillation; corrections 1 to 12; correction for rate of time-keeper; Paris meridian clock; diagram; Staud und Gang von Serffert, 1876, April 15–June 16; Kew; comparison of chronometers, diagram; Hoboken; table of instrumental constants; comparison of chronometers; instrumental constants; rates of chronometers graphically represented; diagrams Nos. 31 to 35; correction for arc; tables showing times of reading half amplitudes; Paris, Berlin, Kew; table of decrement of arc from 1° 10′; diminution of arc; decrement of pendulum arc, Hoboken, N. J.; times of reaching different amplitudes; tables; diagram 36; reduction to a vacuum; coefficient of expansion; diagrams $37^a$, $37^b$; comparison of meters "A" and "49"; correction for wearing of the knife-edges; correction for slip of the knife-edges; correction for shorter length with heavy end up; for flexure of the support; length of the pendulum; on the tenths of millimeters at the ends of the United States Coast Survey pendulum-meter, and on the screw revolutions of the Repsold Vertical Comparator; value of the screw-revolutions of the upper microscope; of the lower microscope; results of observations of length; summary of results of comparison of lengths between the standard meter "49," and others; comparison of Prussian and United States pendulum standards, 1875; concluded length of the pendulum; center of mass; periods of oscillation and values of gravity; diagram; length of seconds pendulum at Geneva; tables of experiments, Paris, 1876, Berlin, Kew, Hoboken, N. J. |
| 1876 | 15 | 410 | Addendum to Appendix No. 15.<br>Tables showing the modes of reducing the experiments. |
| 1877 | †6 | 84–95 | The Pamplico-Chesapeake arc of the meridian, and its combination with the Nantucket and the Peruvian arcs, for a determination of the figure of the earth from American measures.—C. A. Schott.<br>Base-lines; latitudes; resulting azimuths determined astronomically; conditional equations; combination of arcs of the meridian; resulting conditional equations of each arc of the meridian; Nantucket arc; Pamplico-Chesapeake arc; Peruvian arc; combination of arcs for determining the figure of the earth considered as a spheroid; table of data for figure of the earth, Bessel, 1841, Clarke, 1866, Coast Survey, 1877. |

## GEODESY—Continued.

### ARC MEASURES AND LOCAL DEFLECTIONS OF THE PLUMB-LINE—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1879 | †8 | 110–123 | Comparisons of local deflection of the plumb-line.—C. A. Schott.<br>Determination of the standard geodetic latitude; table of systematic apparent deflections in the meridian; determination of the standard geodetic azimuth; table of systematic deflection, at right angles to the meridian, resulting from observed azimuths; determination of the standard geodetic longitude; exhibition of the apparent local deflections of the vertical with reference to Bessel's and Clarke's spheroids; table of comparison of effect of apparent local deflection of the vertical in latitude for Bessel's and Clarke's spheroids; table of same for deflections in azimuth; in longitude. Appendix A, table 1, astronomical latitudes of the oblique arc along the Atlantic; 2, comparison of the register latitudes, apparent deflection in the meridian. Appendix B, table 1, astronomical azimuths of the oblique arc along the Atlantic; 2, comparison of the register azimuth, apparent deflection of the meridian, and corresponding apparent deflections in the prime vertical. Appendix C, table 1, astronomical (telegraphic) longitudes of the oblique arc along the Atlantic; 2, comparison of the register longitudes, apparent deflections in longitude, and corresponding apparent deflections in the prime vertical. |

### GEOGRAPHICAL POSITIONS AND PROJECTIONS.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1851 | 12 | 162–442 | List of geographical positions determined by the Coast Survey.<br>Sections; method of triangulation and verification; average error; assumed size and form of the globe; station-errors; checking of geodetic longitudes by telegraph; longitude of Cambridge from Greenwich; explanation of tables; list.—[Errata, 168, 169, 218, 304, 324, 372, 374, 375, 378: 1851, p. viii; Errata, 163, 169, 189, 190, 191, 194, 217, 218, 220, 258, 271, 276, 286, 324, 360, 372, 374, 375, 378, 400, 402, 404, 409, 416, 425, 480: 1853, p. *181; Errata, 185, 252: 1854, p. xii; Errata, 192, 225, 340, 341, 342, 344, 346, 411: 1855, p. xviii.] |
| 1853 | 7 | *14–*42 | List of geographical positions.—[Errata, *15, *16, *et. seq.*, *17, *20, *28, *29, *31, *32, *33, *34, *36, *42: 1854, p. xii; Errata, *19, *20: 1855, p. xviii.] |
| 1853 | 39 | *96–*163 | Tables for projecting maps, with notes on map-projections.—C. A. Schott and E. B. Hunt.<br>Map-projections classified and defined; Bonne's or modified Flamstead's projection; the polyconic, its properties and varieties; formulas used for the computation of projection-tables in use at the Coast Survey Office; graphic construction of polyconic projections—Coast Survey methods; rectangular polyconic method; Table I, relation between the measures of length used in different countries; II, for converting (A) meters into statute miles; (B) statute miles into meters; (C) meters into yards; (D) yards into meters; (E) yards into miles; III, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; IV(A), length of a degree of longitude between the parallels of 17° and 50°, for each degree of latitude, expressed in nautical miles; (B) length of a degree of longitude between the parallels of 17° and 50° for each degree of latitude, expressed in statute miles; V (A), length in meters of 1° of latitude and longitude for each degree of latitude between 17° and 50°; (B) co-ordinates of curvature for each degree of longitude from 1° to 35°, between latitudes 17° and 50°; VI, projection-tables, giving latitude and longitude arcs, and co-ordinates of curvature, from latitude 24° to 50°.—[Errata, *96, *97, *98, *102, *134: 1853, p. 182; Errata, *101, *113, *114, *115, *116, *130, *159: 1854, p. xii; Errata, *132, *137: 1866, p. xx.] |
| 1855 | 8 | 119–148 | List of geographical positions.—[Errata, 138–140: 1856, p. xx.] |
| 1856 | 58 | 296–307 | Projection-tables.—J. E. Hilgard.<br>Tables applicable to the projection of maps of large extent and minimum distortion in represented area; method; earth's dimensions; Table I, of co-ordinates for projecting the points of intersection of meridians and parallels; II, length, in meters, of one degree of latitude and longitude from latitude 20° to 54°; values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitude; III, tables for converting measures (A) of meters into statute miles; (B) of statute miles into meters; (C) of meters into yards; (D) of yards into meters; (E) of yards into miles; IV, length of a degree of the meridian in nautical and statute miles for each fifth degree of latitude between 20° and 50°; V, length of a degree of longitude for each degree of latitude from 19° to 54°, expressed in nautical and statute miles; VI, radii and polyconic development of a sphere with radius = 1. |
| 1857 | 25 | 264–301 | List of geographical positions. |
| 1859 | 20 | 216–277 | List of geographical positions. |
| 1859 | 33 | 328–358 | Projection-tables for maps of large extent.—J. E. Hilgard.<br>Table I, length in meters of 1° of latitude and longitude, values of the corresponding radii of the developed parallel, and angles at each pole for 10° of longitnde; II, co-ordinates of curvature. |
| 1864 | 15 | 144–182 | List of geographical positions. |
| 1865 | 9 | 99–136 | List of geographical positions in Sections V, VI, VII, and IX. |
| 1865 | 10 | 137 | List of geographical positions determined approximately in West Virginia, Kentucky, Tennessee, Alabama, Mississippi, and Missouri. |
| 1865 | 20 | 176–186 | Projection-tables for a map of North America.<br>Diagram; table of lengths, in meters, of 5° of latitude on the straight meridian; table of the radii of the parallels, and 5° of longitude on each parallel; I, table of co-ordinates, latitude 5° to 85°; II, co-ordinates of curvatures, latitude 55° to 89°; III, length, in meters, of 1° of latitude and longitude 55° to 89°. |

## GEODESY—Continued.

### GEOGRAPHICAL POSITIONS AND PROJECTIONS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1868 | 13 | 171–242 | List of geographical positions determined by the Coast Survey. |
| 1857 | 23–24 | 223–264 | List of topographical and hydrographic sheets, showing their titles, dates, scales, and register-numbers, as filed in the office. |
| 1859 | 18–19 | 212–216 | List of topographical and hydrographic sheets continued. |
| 1861 | 13–14 | 176–180 | List of topographical and hydrographic sheets continued. |
| 1863 | 15–16 | 143–146 | List of topographical and hydrographic sheets continued. |
| 1865 | 8 | 50–99 | List of topographical and hydrographic sheets continued. |
| 1867 | 18A | 265–274 | List of topographical and hydrographic sheets of Alaska, by Russian authority. |
| 1871 | 5 | 84–92 | List of original topographical and hydrographic sheets registered in the archives of the United States Coast Survey from January 1, 1866, to December 31, 1871.. |
| 1873 | 6–7 | 82–93 | List of original topographical and hydrographic sheets registered in the archives of the Coast Survey from June, 1865, to January, 1873. |
| 1874 | †6 | 62–65 | Geographical positions of prominent places in the United States. |
| 1874 | 11 | 134 | Additional geographical positions determined astronomically by the Coast Survey on and near the western coast. |
| 1875 | †7 | 89–114 | Original topographical sheets registered in the archives of the Coast Survey from January, 1834, to July, 1875 (No. 1 to 1378, inclusive). |
| 1875 | †8 | 115–138 | List of hydrographic sheets, geographically arranged, registered in the archives of the Coast Survey from January, 1835, to July, 1875 (Nos. 1 to 1244, inclusive). |
| 1877 | †15 | 191–192 | A quincuncial projection of the sphere.—C. S. Peirce.<br>Tables I, II, of rectangular co-ordinates. Diagram. |
| 1880 | †15 | 287–296 | Comparison of the relative value of the polyconic projection used in the Coast and Geodetic Survey, with some other projections.—C. A. Schott.<br>(Six plates and a chart.)<br>Map-projections classified and defined; three groups; first group: the square projection, the rectangular projection, the rectangular equal-surface projection, Cassini's projection, projection with converging meridians, projection by development of an intersecting cylinder, Mercator's projection; second group: Flamsteed's projection, De Lorgna's, Babinet's equal-surface projection, De l'Isle's conic projection, the simple conic projection, Murdoch's projection; third group: Lambert's projection, Bonne's, the polyconic; remarks on the history of Coast Survey projections; formulæ for computation: 1, for an arc of a great circle of the sphere; 2, for the rhumb-line on Mercator's projection; 3, for the straight line on Bonne's projection; 4, for the straight line on the polyconic projection; resulting distances, in nautical miles; resulting azimuths. |

## HYPSOMETRY.

### SPIRIT-LEVELING.

| | | | |
|---|---|---|---|
| 1854 | 34 | *95–*103 | Measurement of heights.—T. J. Cram.<br>Experimental comparison of the methods of measuring heights by leveling, by vertical angles, by the barometer, and by the boiling-point apparatus.—[Errata, 102: 1855, p. XIX.] |
| 1860 | 38 | 397 | Table of heights for the use of topographers.—C. A. Schott.<br>Height in feet corresponding to a given angle of elevation and a given distance in meters, for use in the construction of contour-lines by plane-tables. |
| 1870 | 7 | 75–76 | Report on the leveling-operations between Keyport, on Raritan Bay, and Gloucester, on the Delaware River, to determine the heights above mean tide of the primary stations Beacon Hill, Disborough, Stony Hill, Mount Holly, and Pine Hill.—R. D. Cutts.<br>Heights above mean-tide, determined by the spirit-level, p. 75; tidal stations, p. 75; instruments, p. 75; tidal observations and records, p. 76. |
| 1870 | 9 | 90–91 | List of heights, above the half-tide level of the ocean, of trigonometrical stations determined by the United States Coast Survey. |
| 1871 | 11 | 154–170 | Comparison of the methods of determining heights by means of leveling, vertical angles, and barometric measures, from observations at Bodega Head and Ross Mountain, California.—George Davidson, C. A. Schott.<br>1, Result of the leveling operations; 2, results of hourly observations of reciprocal and simultaneous zenith distances for difference of heights of the two stations; Tables 1 to 6, zenith distances, atmospheric pressure, &c.; reduction of zenith distances; diagrams; 3, results of hourly observations of atmospheric pressure for difference of heights of the stations; diagrams. |
| 1879 | †15 | 202–208 | Precise leveling.—O. H. Tittman.<br>Instruments and methods used in the Coast and Geodetic Survey (Sketch No. 53); description of level; rod and target; adjustments (Figs. 1 to 6); verification and adjustments of the rods; methods; 1, simultaneous double leveling in one direction; 2, leveling in opposite directions; method of observing (*a*, *b*, *c*, *d*); river crossing; bench-marks; degree of precision; records and computations; curvature and refraction; temperature correction; table of curvature and refraction; form of record; form of computation; form of abstract of results. |

## HYPSOMETRY—Continued.

### SPIRIT-LEVELING—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1879 | †16 | 212–213 | Refraction on lines passing near a surface of water, from observations made at different elevations across the Potomac River.—Andrew Braid.<br>Summary of results. |
| 1880 | †11 | 135–144 | Geodetic leveling on the Mississippi River.—Andrew Braid.<br>Bench-marks; instrument; rods; method of observing; specimen of record; probable and mean error; abstract of results; sketches 45, 46, 47. |

### TRIGONOMETRIC AND BAROMETRIC HEIGHTS.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1854 | 34 | *95–*103 | Measurement of heights.—T. J. Cram.<br>Experimental comparison of the methods of measuring heights by leveling, by vertical angles, by the barometer, and by the boiling-point apparatus.—[Errata, 102: 1855, p. XIX.] |
| 1868 | 7 | 124–129 | Trigonometrical leveling.—R. D. Cutts.<br>1. By reciprocal zenith distances; 2, by zenith distances measured at one station; 3, by observed zenith distances of the sea horizon; 4, by observed angles of elevation or depression. |
| 1870 | 8 | 77–89 | Report on the results of barometrical observations made in connection with the line of spirit-leveling from Raritan Bay to the Delaware River to determine the heights, &c.—R. D. Cutts.<br>Comparison of instruments and the determination of personal errors, pp. 77–81; the computations, pp. 81–89. |
| 1870 | 9 | 90–91 | List of heights, above the half-tide level of the ocean, of trigonometrical stations determined by the United States Coast Survey. |
| 1871 | 11 | 154–170 | Comparison of the methods of determining heights by means of leveling, vertical angles, and barometric measures, from observations at Bodega Head and Ross Mountain, California.—George Davidson, C. A. Schott.<br>1, Result of the leveling operations; 2, results of hourly observations of reciprocal and simultaneous zenith distances for difference of heights of the two stations; tables 1 to 6, zenith distances, atmospheric pressure, &c.; reduction of zenith distances; 3, results of hourly observations of atmospheric pressure for difference of heights of the stations; diagrams. |
| 1871 | 12 | 171–175 | Report on the leveling operations between Keyport, on Raritan Bay, and Gloucester, on the Delaware River, to determine the height above mean tide of the primary stations Beacon Hill, Disborough, Stony Hill, Mount Holly, and Pine Hill.—R. D. Cutts.<br>Tidal stations; instruments; field operations and records; Tables I to V. |
| 1876 | †16 | 338–353 | Reprint of Appendix II, Report of 1871. |
| 1876 | †17 | 355–367 | Observations of atmospheric refraction.—Contribution No. II.—C. A. Schott.<br>Determination of several heights by the spirit-level, and measures of refraction by zenith distances; also, observations of the barometer at Ragged Mountain, Maine, by F. W. Perkins.<br>A, results of the operations by spirit-level executed near the entrance of Penobscot Bay in 1874; B, results of observations of zenith distances at Ragged Mountain for atmospheric refraction; tables; diagram; meteorological observations; C, meteorological observations at Ragged Mountain, at Mount Desert, and at White Head Light; two short simultaneous sets; resulting differences of height. |
| 1876 | †18 | 368–387 | Atmospheric refraction and adjustment of hypsometric measures.—Contribution No. III.—C. A. Schott.<br>Determination of the co-efficient of refraction from zenith distances observed in Northern Georgia by Assistants C. O. Boutelle and F. P. Webber in 1873 and 1874, and adjustment of difference of heights by the method of least squares: 1, results of atmospheric refraction observed at stations in Northern Georgia in 1873–1874; tabulated zenith-distances; determination of the co-efficient of refraction from observed zenith distances; resulting values for co-efficient of refraction; 2, computation of heights of stations from measured difference of height, with application of the method of least squares; heights above mean sea-level; adjustment of results; formation of conditional equations; equations of correlatives; normal equations; probable error of resulting heights; additional remarks and examples for adjustment of heights measured under conditions different from those obtained above; table of log. M, and log. N; table of logarithms of radius of curvature to the earth's surface for various latitudes and azimuths, based upon Clarke's ellipsoid of rotation (1866), and for the metric unit. |
| 1876 | †19 | 388–390 | Hypsometric formulæ, based upon thermodynamic principles.—C. A. Schott. |

## SURVEYING.

### TOPOGRAPHY.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1855 | 21 | 162–163 | New York City.—Report of F. H. Gerdes on his topographical survey of Manhattan Island. |
| 1855 | 22 | 164 | Report on topography executed by the party of Assistant S. A. Gilbert on the western and southern sides of Long Island. |
| 1855 | 23 | 164–165 | Report on topography executed by the party of Assistant A. M. Harrison on the coast of New Jersey. |
| 1856 | 48 | 281–282 | Comparative maps, New York Harbor.—A. Boschke.<br>**Method of survey.** |

## SURVEYING—Continued.

### TOPOGRAPHY—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1860 | 38 | 397 | TABLE OF HEIGHTS FOR THE USE OF TOPOGRAPHERS.—C. A. Schott.<br>Height in feet corresponding to a given angle of elevation and a given distance in meters, for use in the construction of contour-lines by plane-tables. |
| 1865 | †22 | 203–231 | TREATISE ON THE PLANE-TABLE AND ITS USE, with diagrams.—A. M. Harrison.<br>Description; adjustments; paper; scales; projections for field-work; three-point problem; practicable modes of determining the position of a fourth point by resection upon three fixed points; Lehmann's method; Netto's method; Bessel's methods; two-point problem; field-work; contours; example; table of heights; chain; telemeter; table for reduction of hypothenuse to base; reconnaissance; office-work.—[Sketches, 30, 31, 32.] |
| 1880 | †13 | 172–200 | TREATISE ON THE PLANE-TABLE AND ITS USE IN TOPOGRAPHICAL SURVEYING.—E. Hergesheimer.<br>Description; alidade, new style; old style; adjustments; field-work; three-point problem; by construction; by trigonometry; determination of position by resection; Bessel's method by inscribed quadrilateral; by construction of similar triangles; practicable modes of determining, from the triangle of error, the position of a fourth point by resection upon three fixed points; Lehmann's method; Netto's method; two-point problem; representation of the terrene; table of heights; example; formula for determining heights by a vertical angle and distance; example; comparison of feet and meters; regular and irregular method of determining curves; adjustment of the new alidade for observation of altitudes; example; distance; stadia; composed of two parts, rod and telescope with vertical arc; focal distance; its relation to the distant object; table for reduction of hypothenuse to base; projection for field sheets.—[Illustrations 49 to 61.] |

### HYDROGRAPHY.

| | | | |
|---|---|---|---|
| 1852 | 14 | 97–98 | SCREW-PILE SIGNALS along Florida Reef.—James Totten. |
| 1853 | 37 | *93–*94 | ALIGNING REFLECTOR or interranger, Hunt's.—E. B. Hunt. |
| 1855 | 16 | 157–160 | FLORIDA REEF SCREW-PILE BEACONS.—Description of signals.—James Totten. |
| 1855 | 56 | 361 | SPECIMEN-BOX.—B. F. Sands.<br>Instrument for procuring specimens of bottoms in sounding.—[Sketch 55.] |
| 1855 | 60 | 365–366 | SAND'S HYDROGRAPHIC SIGNAL—B. F. Sands.<br>Description and drawing of his gas-pipe signal used in the breakers on Dog Island Bar.—[Sketch 54.] |
| 1857 | 13 | 150–151 | METHOD OF SWEEPING.—(*See* Depths at Hell Gate, &c.) |
| 1857 | 47 | 398–401 | SOUNDING-APPARATUS.<br>New method proposed by E. B. Hunt for sounding in moderate depths. |
| 1857 | 48 | 401–402 | EXPERIMENTAL SOUNDINGS made with Hunt's sounding-apparatus.—W. G Temple. |
| 1860 | 39 | 398 | SOUNDING-APPARATUS (specimen), Mitchell's, for shallow water.—[Sketch 40.] |
| 1856 | 18 | 133–137 | DEPTHS IN CHANNEL-ENTRANCES of harbors, rivers, ports, and anchorages on the coasts of the United States. |
| 1857 | 21 | 178–184 | The same.—[Errata, 182, 183: 1857, p. xviii.) |
| 1859 | 15 | 168–171 | The same. |
| 1862 | 5 | 86–92 | The same. |
| 1874 | †7 | 66–71 | The same. |

## PHYSICAL HYDROGRAPHY.

### TIDES, CURRENTS, AND WINDS.

| | | | |
|---|---|---|---|
| 1845 | 3 | 41–43 | REMARKS ON THE CURRENTS IN MISSISSIPPI SOUND and changes in the magnetic variation.—F. H. Gerdes. |
| 1846 | 8 | 68–70 | TIDES AT THE ENTRANCE OF MOBILE BAY.—C. P. Patterson. |
| 1850 | 8 | 80–81 | ENCROACHMENT OF THE SEA on the south side of Long Island.—Prof. A. G. Pendleton. |
| 1850 | 9 | 81–82 | PROGRESS OF SANDY HOOK FROM 1848 TO 1850.—H. L. Whiting. |
| 1851 | 7 | 127–136 | NOTES ON CAT ISLAND TIDES.—A. D. Bache.<br>Discussion; table of diurnal and semi-diurnal curves.—[Sketch 35 (H, Nos. 2–6).] |
| 1851 | 8 | 136–137 | GRAPHICAL METHOD of representing current-observations, as used in the Coast Survey.—A. D. Bache.—[Sketch 3 (A, No. 3).] |
| 1851 | 28 | 482–484 | BEAUFORT HARBOR, NORTH CAROLINA.—H. L. Whiting.<br>Operative causes of its physical permanency.—[Sketch 17 (D, No. 5).] |
| 1851 | 31 | 488–494 | FLORIDA COAST RECONNAISSANCE.—F. H. Gerdes.<br>A, Description; B, survey; C, tides and currents; D, railroad across the peninsula; E, light-houses and buoys; F, general remarks on Cedar Keys Harbor.—[Sketches 27, 28, and 29.] |
| 1851 | 50 | 528–530 | SAN DIEGO RIVER ENTRANCE.<br>[Sketches 6 and 7.]—(*See* C, statistics; *a*, coast, western.) |
| 1851 | 56 | 553–558 | HELL GATE CHANNEL.—W. A. Bartlett.<br>Examination of reefs and changes produced by blasting.—[Sketch 8 (B, No. 4).]—[Errata, p. ix.] |
| 1852 | 8 | 84 | ON POT ROCK, HELL GATE.—W. A. Bartlett. |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1852 | 22 | 111–122 | Discussion of Cat Island tides.—A. D. Bache.<br>Table I, Sketch 1, diurnal and semi-diurnal curves deduced from observations, with curves of sines; (A) diurnal-wave; heights and times; II, Sketch 2, maximum ordinates of diurnal curve, &c.; III, Sketch 3, effect of sun's declination on height; IV, effect of moon's parallax; V and VI, co-efficients; VII, computed diurnal ordinates compared with observations; VIII, Sketch 8, residuals classed by moon's ages; IX, same, corrected by change of cosines; X, difference of diurnal maximum ordinates, from last and from first methods of groups—semi-diurnal effect; XI, correction to maximum diurnal ordinate for high-water ordinate; XII to XV, further residual corrections; comparison with hypothesis; (B) semi-diurnal curve; XVI, half-monthly inequality in height; XVII, discrepancies between observations and formula.—[Sketch 25 (H, Nos. 5–9).]—[Errata, p. 115, 119, 121; 1853, p. 182.] |
| 1853 | 27 | *71–*76 | Notes on tides at Key West.—A. D. Bache.<br>Table I, half-monthly inequality of tides, one year's observations; II, diurnal inequality, with formula; decomposition of the curves of observation; semi-diurnal tides; III, first six months; IV, second six months; V, the whole year; diurnal tides; VI, effect of moon's declination; VII, moon's age; changes of mean level; VIII, height of high water referred to moon's age, first and second months; IX, monthly mean level.—[Sketches 27 (F, No. 4) and 28 (F, No. 5).] |
| 1853 | 28 | *77–*81 | Notes on tides at Rincon Point, Cal.—A. D. Bache.<br>[Tables I to IV.]—[Sketch 48 (J, No. 7).] |
| 1853 | 29 | *81–*82 | Notes on the tides at San Francisco, Cal.—A. D. Bache. |
| 1853 | ........ | ........... | Sandy Hook changes.<br>[Sketch 8 (B, No. 3).] |
| 1853 | 38 | *94–*96 | Self-registering tide-gauge, Saxton's.—E. B. Hunt.<br>[Sketch 54.] |
| 1854 | ........ | ........... | Craven's current-indicator.<br>[Sketch 55.] |
| 1854 | 14 | *21–*23 | Beaufort Harbor, North Carolina.—J. N. Maffit.<br>Its capacity, changes, and improvements.—[Sketch 23.] |
| 1854 | 29 | *35–*37 | Nantucket and Vineyard Sound tides.—H. Mitchell.<br>Method of securing Mitchell's tide-gauge; remarks on swells.—[Sketch 57.] |
| 1854 | 30 | *37–*40 | Western coast tidal and magnetic observations.—W. P. Trowbridge. |
| 1854 | 45 | *147–*152 | Co-tidal lines, Atlantic.—A. D. Bache.<br>Preliminary determinations of co-tidal lines on the Atlantic coast of the United States, from Coast Survey observations. Table I, observations for co-tidal hours; II, co-tidal hours of ports on the Atlantic coast; III, rate and trend of co-tidal lines.—[Sketch 26.]—[Errata, 151: 1855, p. xix.] |
| 1854 | 46 | *152–*155 | Diurnal inequality, western-coast tides.—A. D. Bache.<br>Comparison of the diurnal inequality of the tides at San Diego, San Francisco, and Astoria, with tables.—[Sketch 49.]—[Errata, 153: 1855, p. xix.] |
| 1854 | 48 | *161–*166 | Nantucket Shoals current.—C. A. Schott.<br>On the currents of Nantucket Shoals, from Coast Survey current observations.—Table I, mean direction; II, maximum velocity; III, groups of luni-current intervals.—[Sketch 13 (A, No. 12).]—[Errata, pp. 165, 166: 1855, p. xix.] |
| 1854 | 49 | *166–*168 | Muskeget Channel and Martha's Vineyard currents.—C. A. Schott.<br>Table showing the currents and rate of current in Muskeget Channel and of the northeast coast of Martha's Vineyard; velocity of current; duration of ebb, flood, and slackwater; current-establishments.—[Sketch 14 (A, No. 13); also, 1855, Sketch 6.]—[Errata, pp. 167, 168: 1855, p. xix.] |
| 1854 | 50 | *168–*179 | Tides, Long Island Sound and approaches.—C. A. Schott.<br>Table I, range, or mean rise and fall of tides, to April, 1853; II, corrected or mean establishments, to April, 1853; III, set and maximum rates of ebb and flood streams; IV, luni-current interval for beginning of outgoing streams; eastern part of the sound, 1846–'47; western part of New York Bay and channel, 1844; New York Harbor, 1844–'45; Hell Gate, 1845; Hell Gate and Throg's Neck, 1846; V, mean duration of slack-waters and of respective ebb and flood streams, from the middle (time) of one slack-water period to that of the next; VI, irregularity of luni-current intervals of successive tides.—[Sketch 16 (B, No. 2).]—[Errata, pp. 172, 174: 1855, p. xix.] |
| 1854 | 52 | *189–*190 | Current-bottles.<br>One from Mobile Bay to Mosquito Inlet; and one from Cape Florida to Jupiter Inlet. |
| 1854 | 53 | *190–*191 | Sea-coast tide-gauge.—H. Mitchell.<br>Description of his tide-gauge used at stations on the open sea-coast and in situations exposed to stormy currents.—[Sketch 57.]—(*See, also,* *35–*37.)—[Errata, for Sketch K read Sketch 57.] |
| 1855 | 23 | 164–165 | Sandy Hook changes.—[*See* New Jersey, &c.]—A. M. Harrison.<br>[Sketch No. 9.] |
| 1855 | 24 | 170–171 | Remarks by Mr. Boschke on surveys made at different periods in New York Harbor. |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1855 | 33 | 222-223 | Nantucket Sound.—H. Mitchell.<br>Tidal observations; interference-phenomena. |
| 1855 | 50 | 338-342 | Pacific co-tidal lines.—A. D. Bache.<br>Tidal observations.—Table I, tide-stations on the western coast of the United States; II, data for co-tidal lines of the Pacific coast of the United States; co-tidal hours; co-tidal groups; III, discussion of the middle group between Cape Mendocino and Point Conception.—Chart of co-tidal lines.—[Sketch 49.] |
| 1855 | 52 | 346-347 | Gulf of Mexico tides.—A. D. Bache.<br>Observations and type-curves at the several stations, showing their decomposition into diurnal and semi-diurnal tides. |
| 1856 | 34 | 249-251 | Prediction-tables.—A. D. Bache.<br>Notes on the progress made in their preparation with reference to tides of Boston Harbor. |
| 1856 | 35 | 252-260 | Co-tidal lines, Gulf of Mexico.—A. D. Bache.<br>Discussion and preliminary determination.—Table I, diurnal wave; II, stations, &c.; III, diurnal intervals; IV, tide-elements of the stations; V, semi-diurnal tides; VI, comparison of establishments of diurnal and semi-diurnal tides in the Gulf of Mexico.—[Sketches 35 and 36.] |
| 1856 | 36 | 260-261 | Type-curves, Gulf of Mexico.<br>Descriptive references to Sketch No. 38, representing the decomposition of curves of observations.—[Sketch 38.] |
| 1856 | 37 | 261-263 | Interference-tides.—H. Mitchell.<br>On observations made in Nantucket and Martha's Vineyard Sounds. |
| 1856 | 38 | 263-264 | Tidal currents at Sandy Hook.—A. D. Bache.<br>Notes on the causes of northwardly increase of the peninsula.—[Errata, p. 264: 1856, p. xx.] |
| 1856 | 39 | 264-266 | New York Harbor and dependencies.—H. Mitchell.<br>On tidal and current observations made in New York Harbor, city docks, Newark Bay, and the Kills. |
| 1856 | 40 | 266-267 | Hudson River.—G. Würdemann.<br>On tidal observations made between Albany and New York City.—[Sketch 6.] |
| 1856 | 43 | 271-272 | Winds of Albemarle Sound.—L. F. Pourtales.<br>Discussion of their effect upon the tides.—[Sketch 16.] |
| 1856 | 44 | 272-276 | Winds in the Gulf of Mexico,—A. D. Bache.<br>Discussion relative to the disturbance caused in the intervals of successive tides at several stations on the Gulf coast; Table I, quantity and direction of wind at Key West, Fla., 1851-'52; II, at Fort Morgan, Ala., 1847-'49; III, at Galveston, Tex. |
| 1856 | 45 | 276-278 | Winds and tides in Cat Island Harbor.—Results deduced from observations made by G. W. Dean.—[Sketch 39 ] |
| 1856 | 46 | 279-280 | Cards from current-bottles.<br>Picked up on the shore of Loggerhead Key, Fla., and on the North Caicos, Bahamas. |
| 1857 | 16 | 152-153 | Beaufort Harbor, North Carolina.—C. R. P. Rodgers<br>Present condition of bar and anchorage.—[Sketches 29 and 30.] |
| 1857 | 17 | 153-155 | Cape Fear Entrances, North Carolina.—J. N. Maffit.<br>Elements of physical changes wrought.—[Sketch 33; also, 1855, Sketch 16.] |
| 1857 | 33 | 342-347 | Atlantic coast tides.—Generalization of heights relative to the configuration of the coast.—A. D. Bache.<br>Table I (A), heights of tides on the Atlantic coast of the United States; II (B), on the coast of Cape Breton and New Brunswick.—[Sketch 65.] |
| 1857 | 35 | 350-354 | Tides and currents in the Nantucket and Vineyard Sounds and in East River.—H. Mitchell.<br>Hell Gate and vicinity; tides and currents; Hudson River levelings; Nantucket and Martha's Vineyard Sounds, tides and currents. |
| 1857 | 36 | 354-358 | Winds of the western coast.—A. D. Bache. |
| 1857 | 37 | 358-373 | New York Harbor; report of advisory council.<br>Physical causes of changes: 1, changes at Sandy Hook; 2, northern side of entrance, Coney Island and south shore of Long Island; 3, New York bar; 4, New York Upper Bay; 5, Newark Bay; 6, Hudson River; 7, East River to Throg's Neck; statistic extracts. - [Errata, p. 272: 1858, p. xx.] |
| 1857 | 49 | 402-403 | Tide-gauge, Trenchard's.<br>[Sketch 72.] |
| 1857 | 50 | 403-404 | Tide-gauge for deep water, Mitchell's.<br>[Sketch 72.] |
| 1858 | 13 | 150-151 | Cape Fear Entrances.—T. B. Huger.<br>Recent changes in its hydrography.—[Sketches 12 and 13.] |
| 1858 | 27 | 197-203 | New York Bay and Sandy Hook.—A. D. Bache.<br>On the character of the tidal currents in the vicinity of the bar: 1, normal currents at the entrance to New York Bay; 2, False Hook Channel and the approaches; 3, currents of Sandy Hook Bay.—Table I to IV, lunar time, duration, velocity, and direction of currents; V and VI, velocities corrected for diurnal and half-monthly inequalities.—[Sketch 39.] |
| 1858 | 28 | 204-207 | East River and New York Bay.—H. Mitchell.<br>On the observations of surface and sub-currents. |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1858 | 30 | 210–213 | Co-tidal lines of an inclosed sea, as derived from the equilibrium-theory.—Benjamin Peirce.<br>1, general theory ; 2, its modification by the incompleteness of the inclosure. |
| 1858 | 31 | 213–216 | Dynamics of ocean currents.—E. B. Hunt. |
| 1858 | 38 | 247–248 | Sounding-apparatus and tide-meter, proposed by E. B. Hunt.—J. M. Batchelder.<br>Notes on its principles and application. |
| 1859 | 26 | 311–317 | New York Harbor.—H. Mitchell.<br>On its physical survey, with description of apparatus for observing the currents—[Sketch 40.]—[Errata, p. 317; 1860, p. xx.] |
| 1859 | 28 | 320–321 | Current-cards thrown from the surveying-steamer Corwin, and found on the eastern coast of Florida. |
| 1859 | 35 | 365–366 | Tide-meter—J. M. Batchelder.<br>Results of experiments made with the apparatus devised by E. B. Hunt. |
| 1860 | 41 | 399–*402 | Labrador expedition.—A. Murray.<br>Report of a voyage of steamer Bibb, and remarks on the winds and tides. |
| 1862 | 9 | 126–128 | Co-tidal lines of the Gulf of Mexico, deduced from recent observations.—A. D. Bache.<br>Tables of diurnal and semi-diurnal tides.—[Sketch 46.] |
| 1864 | 6 | 57 | Beaufort Harbor.—E. Cordell.<br>Development of changes at the bar and in the channel.—[Sketch 26.] |
| 1864 | 9 | 91–92 | Tides at Tahiti, South Pacific Ocean.—Their general character.—J. Rodgers.<br>[Sketch 40.] |
| 1865 | 5 | 45 | Entrance to Cape Fear River, North Carolina.—J. S. Bradford.<br>Hydrographic changes.—[Sketch 13.] |
| 1865 | 11 | 138 | Explanation of diagram of type-curves of the tides on the Pacific coast.<br>[Sketch 26.] |
| 1866 | 6 | 44–46 | Hell Gate tides (East River, N. Y.).—H. Mitchell.<br>Preliminary report on the interference-tides of Hell Gate, with directions for reducing the sounding.—Table of relative elevations of tidal planes from his observations; tides and currents of Hell Gate, from observations of 1857. |
| 1866 | 18 | 113–119 | Tidal observations at Cat Island, Gulf of Mexico: Notes of a discussion.—A. D. Bache.<br>(Report for 1851.)—[Sketch 30.] |
| 1853 | 26 | *67–*70 | Tide-tables for the use of navigators, with description of bench-marks, explanations, and examples for use.—A. D. Bache. |
| 1854 | 51 | *180–*189 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 181, 182, 183, 185: 1855, p. xx.] |
| 1855 | 53 | 347–359 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 349, 351, 353, 354, 358: 1857, p. xviii.] |
| 1856 | 17 | 120–133 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 130: 1856, p. xx.] |
| 1857 | 20 | 157–178 | Tide tables for the use of navigators.—A. D. Bache. |
| 1858 | 43 | 275–297 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 279: 1859, p. xvi.] |
| 1859 | 14 | 136–167 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 145: 1860, p. xx.] |
| 1860 | 16 | 131–164 | Tide-tables for the use of navigators.—A. D. Bache. [Errata, 161: 1860, p. xx.] |
| 1861 | 9 | 98–131 | Tide-tables for the use of navigators.—A. D. Bache. |
| 1862 | 8 | 93–126 | Tide-tables for the use of navigators.—A. D. Bache. |
| 1863 | 12 | 84–117 | Tide-tables for the use of navigators.—A. D. Bache. |
| 1864 | 8 | 58–90 | Tide-tables for the use of navigators.—A. D. Bache. |
| 1866 | 7 | 47–49 | Predictions for Eastport, as a specimen. |
| 1867 | 12 | 149–157 | Provincetown Harbor, Massachusetts.—Special survey.—H. L. Whiting. |
| 1867 | 13 | 158–169 | Tides and currents of Hell Gate, N. Y.—H. Mitchell.<br>General scheme of tides and currents: 1, general scheme of tidal interference; observations and results; curves; 2, tides from stations selected as characteristic for New York Harbor and its approaches, 1857–'58, with diagram; intervals and heights of tides from simultaneous observations, May and June, 1857, arranged according to hour of transit; curves of half-monthly inequalities; 4, restoration of level between gauges at Hell Gate Ferry and Pot Cove, 1857; diagram; 5, currents of New York Harbor; general scheme of currents, graphic. |
| 1867 | 14 | 170–175 | Merrimack River, Massachusetts.—H. Mitchell.<br>Surveys respecting its navigation, with tables.—[Sketch 2 ] |
| 1868 | †5 | 51–102 | Discussion of the tides in Boston Harbor.—W. Ferrel.<br>The observations and the locality; expression of the disturbing forces; tidal expressions; object and plan of discussion.—Tables I, II, III, and IV, of average normal values; V, the constant or mean tide; the semi-monthly inequality; VI, inequality depending upon the moon's mean anomaly; VII, inequality depending upon the moon's longitude; VII *bis*, inequality depending upon the sun's anomaly and longitude; VIII, inequality depending upon the moon's node; IX, inequalities depending upon $\eta_8$ and $\eta_9$; diurnal tide; recapitulation of results; comparisons with the equilibrium theory; determination of the general constants; comparisons with the dynamic theory; prediction formulas and Tables I–XI; computation of a tidal ephemeris; conclusion; example of the computation of a tidal ephemeris. |
|  |  | 91–102 | Tidal ephemeris; and Computations.—(*See* Local tides.) |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1868 | 6 | 103–108 | Mode of forming a brief tide-table for a chart, with example.—R. S. Avery.<br>[Sketch 29.] |
| 1869 | 5 | 75–104 | Reclamation of tide-lands, and its relation to navigation.—H. Mitchell.<br>1, general discussion; scour of tidal and river currents; general rule of bar-scouring; parallel works; transverse works; physical history of salt-marshes; shingle-levees; other natural levees; Peirce's criterion; 2, field-work; Green Harbor River; North River; tabular sections of shingle-levees; sand beach; section of slueway formed by Minot's gale; general rise; local changes of heights of tide—tables; effect of a dam; general conclusions relative to the projects of reclamation; shore of Nahant; tabular sections; maps and diagrams (in text). |
| 1869 | 15 | 236-259 | Reports concerning Martha's Vineyard and Nantucket.—H. L. Whiting and H. Mitchell.<br>(A) Edgartown Harbor, changes; Vineyard Haven, its character as a port of refuge and its present condition; Table I, exposure of anchorages in Provincetown Harbor; II, in Vineyard Haven; III, in Great Wood's Hole; IV, in Tarpaulin Cove; V, in Edgartown Roadstead; VI, in Old Stage Harbor; VII, in New Bedford Harbor and Quick's Hole; VIII, in Plymouth Harbor; IX, in Boston Harbor and Nantasket Roads; X, in Boston Harbor and Hull Bay; XI, in Boston Harbor and President's Roads and George's Roads; XII, in Marblehead Harbor; XIII, at Salem Harbor; XIV, at Gloucester Harbor; XV, in Lower Bay, New York Harbor; XVI, in Upper Bay, New York Harbor; XVII, anchorage-room and average exposure in the respective harbors.—(B) surveys of summer, 1871: 1, physical aspect and peculiarities; 2, Edgartown tides, difference of heights; 3, Nantucket tide-table; 4, elements of the field-work. |
| 1870 | 5 | 66–69 | Tabular statement of results of computed tide-tables for charts of the western coast of the United States.—R. S. Avery. |
| 1870 | 6 | 70–74 | Mode of forming brief prediction tide-tables.—R. S. Avery. |
| 1870 | 10 | 92–97 | Description of bench-marks at tidal stations. |
| 1870 | 11 | 98–99 | Extract from a report relative to a method of determining elevations along the course of a tidal river, without the aid of a leveling-instrument by setting up graduated staves at such distances apart that the slacks of the tidal currents extend from one to another.—Rule: the difference in the elevations of the zeros of the gauges is equal to one-half the sum of the differences of their readings at the two slack waters.—Henry Mitchell. |
| 1870 | 20 | 190–199 | On the moon's mass, as deduced from a discussion of the tides of Boston Harbor.—William Ferrel. |
| 1871 | 6 | 93–99 | Meteorological effects on tides.—William Ferrel.<br>Graphic representation of the relative amounts and direction of the wind for each of the four seasons for Boston |
| 1871 | †8 | 110–133 | Harbor of New York, 1873.—Henry Mitchell.<br>Increase of Jersey Flats; diagram A; changes in Buttermilk Channel; changes in the vicinity of Middle Ground Shoal and Gowanus Bay; changes at and near the Sandy Hook entrance; tides and currents; phenomena in the pathway of the Hudson; movement through East River; East River and Hudson tidal current compared; relations of East River movements to those over the bar; tables 1 to 17; diagrams B, C, D.—[Sketches 30, 31, 32.] |
| 1871 | †9 | 134–143 | Nauset Beach and Monomoy Peninsula.—H. Mitchell.<br>Physical history of the neighborhood of Monomoy (Sketch No. 35); recent movement of Chatham Beach in detail; tables. |
| 1871 | †10 | 141–153 | Location of harbor lines.—Henry Mitchell.<br>Value of tidal volume; encroachment on the channels; isodynamic lines (Sketch No. 35); example; anchorage and winding room; requisite depths of frontage; length of slips; riparian rights; laws establishing harbor lines. |
| 1872 | 6 | 69–72 | Field and office work relating to tides.—R. S. Avery. |
| 1872 | 7 | 73–74 | Maxima and minima of tides on the coast of New England for 1873.—William Ferrel. |
| 1872 | †10 | 177–212 | Harbors of Alaska and the tides and currents in their vicinity—W. H. Dall.—[Sketch No. 18].<br>Statistics; notes on the North Pacific current; hydrographic notes on Captain's Bay and vicinity; meteorology of Unalashka; tides of Iliuliuk; compound tides; semi-diurnal tides; tide referred to the lower transits; to the upper transits; semi-diurnal tides; tidal current of Unalashka; the Alaska current; its effect on the climate of the Aleutian district; the circular current of Bering Sea; the Shumagin Islands; western; eastern; miscellaneous hydrographic notes; meteorological observations from September, 1871, to October, 1872; current observations; tides of Iliuliuk. |
| 1872 | 16 | 257–261 | Middle-ground shoal, New York Harbor.—H. Mitchell.<br>Tables of current observations.—[Sketch No. 22]. |
| 1872 | 17 | 262–265 | Shore-line changes at Edgartown Harbor, Mass.—H. L. Whiting.—[Sketch No. 23]. |
| 1873 | 8 | 94–102 | Physical survey of Portland Harbor.—H. Mitchell.<br>Correspondence; sections 1 to 10 for velocities of tidal current; diagrams of the ten sections. |
| 1873 | 9 | 103–107 | Additional report concerning the changes in the neighborhood of Chatham and Monomoy.—H. Mitchell.<br>The real point of interest; corrections of previous paper; results of the last survey, tables, diagrams. |
| 1873 | 10 | 108–109 | Changes in the submerged contours off Sandy Hook —[Tables, diagram].—Henry Mitchell. |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1874 | †12 | 135–147 | Terminal points of the proposed canals through Nicaragua and the Isthmus of Darien.—H. Mitchell.<br>Greytown; history of the harbor; causes of its decline and final destruction; the work of restoration; obstructions of the lower San Juan; recapitulation; result of foregoing discussion; Urabá mouth of the Atrato; conclusions relative to the improvement of the Urabá; Brito; conclusions; Limon and Chiri-Chiri Bays; general exposure. |
| 1874 | †16 | 154 | Ocean salinometer.—J. E. Hilgard. |
| 1875 | 11 | 189–193 | Recent observations at South Pass Bar, Mississippi River. [Sketch No. 24; tables] —H. Mitchell. |
| 1875 | †12 | 194–221 | Discussion of tides in New York Harbor —William Ferrel.<br>General plan and immediate object of the discussion; adopted notations; averages deduced from the observations; Tables I to VI; semi-diurnal tides, half-monthly inequality; lunar parallactic inequality; mean lunar declinational inequality; lunar nodal inequality; solar declinational and parallactic inequalities; mean sea-level; diurnal tide; table VII; comparison of theory with observation; practical application; directions for computing a tidal ephemeris. Appendix: Tables I to IV for computing heights and times of high water; example. |
| 1875 | †18 | 293–314 | Observations on certain harbor and river improvements collected on a voyage from Hong Kong, via Suez, to New York.—George Davidson.<br>Nagasaki; Shanghai; Hong-Kong; Canton; Singapore; Penang; Calcutta; Bombay; Suez and canal; destructive action by passing vessels; current through the canal; saltness of water; tides; breakwater at Port Said; dredging, estimate of cost; Alexandria; Naples; Genoa; Swindemunde; Copenhagen; Kiel; Hamburg; Bremerhafer; Wilkelshafen; Amsterdam Canal; entrance-locks and sluices; the béton blocks; North Sea Harbor Breakwater; design; method of building; dam at Schellingwonde; eastern extremity of the Amsterdam Canal; difficulties of construction; Cherbourg; docks; breakwater; Brest; docks; Admiralty Pier, Dover; construction; cost; Portland breakwater; ripraps; description; cost; Holyhead Breakwater; Alderney Breakwater; conclusions; fascinage for breakwater foundations; river improvements. |
| 1875 | †20 | 369–412 | Meteorological researches for the use of the Coast Pilot.—[Sketches 31 to 37.]—William Ferrel.<br>Prefatory note by C. P. Patterson, Superintendent.<br>Part I. On the mechanics and general motion of tne atmosphere.<br>Chapter I. General equations of the motions and pressure of the atmosphere. |
|  |  | 379 | Chapter II. The temperature and pressure of the atmosphere at the earth's surface obtained from observation; Tables I to V; Tables VI to X of distribution of atmospheric pressure. |
|  |  | 402 | Chapter III. The general motion of the atmosphere; Table XI, velocities; Table XII, direction and velocities. [Errata, §§ 8, 9, 13, 15, 42.] |
| 1876 | 8 | 130–142 | Methods of registering tidal observations.—R. S. Avery.<br>Bench-marks; tide-gauges; self-registering tide-gauges; diagrams; how to use; three-roller gauge; large cylinder gauge; tabulating high and low water; hourly readings; scales of heights; time, precautions. |
| 1876 | †9 | 143–146 | Changes in the harbor of Plymouth, Mass.—H. Mitchell.<br>[Sketch No. 22.] Champlain (1605); Blaskowitz (1774); general conclusions and remarks. |
| 1876 | 10 | 147–185 | Physical survey of New York Harbor.—H. Mitchell.<br>Section XXXVI, Table A; positions of origins and termini of sections examined in 1872–'73–'74–'75; transverse curves of velocity, and perimeters; Sections I to XXXVII. |
| 1876 | 11 | 186–189 | Report concerning the location of a quay or pier-line in the vicinity of the United States navy-yard at New York. —Henry Mitchell.<br>Sections VI to VIII. [Sketch No. 23.] |
| 1876 | 12 | 190–191 | Review of the characteristics of South Pass, Mississippi River.—Henry Mitchell. |
| 1877 | †9 | 104–107 | Apparatus for observing currents.—H. L. Marindin.<br>Description of floats; diagram. |
| 1877 | 10 | 108–113 | Optical densimeter for ocean water.—J. E. Hilgard. |
| 1877 | †14 | 184–190 | Density of the waters of the Chesapeake Bay and its principal estuaries.—Lieut. Frederick Collins.<br>Instruments employed; specific gravity; method of working; explanation of tables in the full report. |
| 1878 | †9 | 121–175 | Physical survey of the Delaware River at Philadelphia.—Henry Mitchell.<br>The channel; form of cross-section; section $7\frac{1}{2}$, Southwest Pass, Mississippi River; diagram A; the Delaware; location of the channel; cross-section; diagram B; table; diagram C; tables; tables of transverse curves of velocity; diagram D. |
| 1878 | †10 | 176-267 | Meteorological researches for the use of the Coast Pilot.—William Ferrell.<br>Part II. On cyclones, water-spouts, and tornadoes.<br>Chapter I. The theory of cyclones. |
|  |  | 206 | Chapter II. Practical application of the theory and comparison with observation. |
|  |  | 243 | Chapter III. Tornadoes, hail-storms, and water-spouts.—[Sketches Nos. 33 to 38.] |
| 1878 | †11 | 268–304 | Tides in Penobscot Bay.—William Ferrel.<br>I. General principal of the harmonic analysis and discussion of tide observations. II, p. 284, analysis of the tides of Pulpit Cove. III, p. 296, comparison of observations with theory. IV, p. 299, practical application. |
| 1879 | †10 | 175–190 | Physical hydrography of the Gulf of Maine.—H. Mitchell.<br>General description; tides and tidal currents; Tables 1 to 7; George's Bank; Tables 8, 9. |

## PHYSICAL HYDROGRAPHY—Continued.

### TIDES, CURRENTS, AND WINDS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1879 | †13 | 199 | Addendum to a report on a physical survey of the Delaware River.—Henry Mitchell. |
| 1880 | †9 | 110–125 | Comparison of the surveys of Delaware River in front of Philadelphia, 1843 and 1878.—H. L. Marindin. Tables 1, 2. Supplement, p. 116; Tables 3 to 10. |
| 1880 | †10 | 126–134 | Comparison of surveys of Mississippi River in the vicinity of Cubitt's Gap.—H. L. Marindin. Tables 1 to 5. [Sketch No. 44.] |
| 1880 | †16 | 297–340 | Bering Sea.—W. H. Dall.<br>Report on the currents and temperatures, and also those of the adjacent waters; sources of information; surface temperature; tables of temperatures; pack ice; summer temperatures; the Kuro Siwo and its extensions; table of North Pacific Sea temperatures; comparison of sea temperatures from observations by the Challenger, 1873 and 1875; currents of Bering Sea; observations of the Tuscarora and Venus; those of Krusenstern, 1804–1806; notes by whalers and others; table of temperatures; of currents; observations off the coast of Asia; in the Arctic in general; in the vicinity of Point Barrow.<br>Supplementary note.—Additional observations in the Arctic Sea; boundary line between the territory of the United States and Russia; diagram of surface and vertical isotherms; chart of currents. |

### GULF STREAM.

| | | | |
|---|---|---|---|
| 1846 | 4 | 46–53 | Letters on the exploration of the Gulf Stream.—Lieut. Com. George M. Bache. |
| 1847 | 11 | 75 | Table showing temperatures at depths below 700 fathoms, taken by Lieut. Coms. C. H. Davis in 1845, George M. Bache in 1846, and S. P. Lee in 1847. (*See* Sketch.) |
| 1853 | ........ | 46–51 | Gulf Stream explorations.—(Report.)—[Sketches 15 and 16.] |
| 1853 | 30 | *82–*83 | Examination of specimens of bottom obtained in Gulf Stream.—L. F. Pourtales. |
| 1854 | 47 | *156–*161 | Gulf Stream temperatures.—A. D. Bache.<br>On the distribution of temperatures on and near the Gulf Stream: 1, at different depths; 2, at the same depths on sections across the axis of the Gulf Stream.—Table I, probable uncertainty in determination of the maximum and minimum points; 3, connection of the figure of the sea-bottom with the distribution of temperature; 4, the "cold wall"; 5, reference to shifting; 6, chart of Gulf Stream.—[Sketches 24 and 25.]—[Errata, p. 158, 159, 160: 1855, xix.] |
| 1855 | ........ | 53–55 | Gulf Stream exploration. (Report.)<br>Programme, Craven's Cape Florida section; Sand's soundings along the Gulf Stream axis; depths; bottom-configuration, temperatures, and bottoms. |
| 1855 | ....... | 84 | Gulf Stream deep-sea soundings.—(Report.)—[Sketch 38 (II, No. 3).] |
| 1855 | 54 | 359 | Bottle-paper.<br>Current-bottle card thrown over near Sandy Hook and picked up at the bar at Santa Cruz, one of the Western Islands. |
| 1855 | 55 | 360 | Gulf Stream bottoms.—J. W. Bailey.<br>On the characteristics of some bottoms from the Cape Florida Gulf Stream section. |
| 1858 | 32 | 217–222 | Florida Gulf Stream.—E. B. Hunt.<br>Notices of certain anomalies; changes of current depending upon the winds and seasons. |
| 1858 | 39 | 248–250 | Analysis, microscopical, of specimens of bottom taken in sounding.—L. F. Pourtales.<br>Green and ochraceous incrustation of *Foraminifera*, and jet tint of specimens. |
| 1859 | 25 | 306–310 | Gulf Stream; distribution of temperature in the water of the Florida channel and straits.—A. D. Bache.<br>Form of bottom; change of temperature with depth; temperature in a direction across the stream; bands of warm and cold water; the "cold wall"; longitudinal section; effects of pressure on Saxton's deep-sea thermometer, under pressure and free from pressure; thermometers Nos. 5 and 10.—[Sketch 35.] |
| 1860 | 17 | 165–176 | Gulf Stream.—A. D. Bache.<br>General account of the methods used in developing its hydrography, and summary of results obtained; 1, instruments for temperatures; for depth; for obtaining specimens of the bottom; 2, plan of the work; 3, method of discussion of results; 4, results; type-curves of law of temperature, with depth at the most characteristic positions; type-curves of law of distribution of temperature across the stream; curves of depths of equal temperatures.—Table I, distance of the cold wall from the shore, and widths of the several bands of cold and warm water of the Gulf Stream, measured on the lines of the sections; 5, limit of accuracy of the determinations; II, probable uncertainty in the determination of maximum and minimum points by running the same sections over in different years, by different observers; III, value of probable error of determination of the bands for each section and the average of the whole; 6, figure of the bottom of the sea below the Gulf Stream; 7, general features of the Gulf Stream.—[Sketches 19 to 22.] |
| 1867 | 15 | 176–179 | Soundings in the Gulf Stream between Key West and Havana.—H. Mitchell.<br>Table I, soundings in the Gulf Stream near the coast of Cuba, 1867; II, current observations.—[Sketch 25.]—(Supplement, 1868, pp. 166–167.) |

## PHYSICAL HYDROGRAPHY—Continued.

### GULF STREAM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1867 | 16 | 180–182 | FAUNA OF THE GULF STREAM.—L. F. Pourtales.<br>Dredgings in the Straits of Florida. |
| 1868 | 11 | 166, 167 | NOTE ON GULF STREAM OBSERVATIONS.—H. Mitchell.<br>Decrease of bottom temperature in still-water channels.—(Sequel to 1867, p. 179, below.) |
| 1868 | 12 | 168–170 | REPORT UPON DREDGINGS NEAR THE FLORIDA REEF.—L. F. Pourtales.<br>Organic specimens; corals, echinoderms, brachiopods, &c. |
| 1869 | 10 | 208–219 | REPORT UPON DEEP-SEA DREDGINGS IN THE GULF STREAM DURING THE THIRD CRUISE OF THE UNITED STATES STEAMER BIBB.—L. Agazziz.<br>Faunæ of the submarine zones; reef-zone; sedimentary zone; coral slope of living cretacean types; floor of foraminiferine mud; geological inferences; inclination of the reefs; pot-holes; formation of oölithic, amorphous, and compact limestones; the Jurassic submarine seam; embryology of corals and formation of colonies by disk-embranchment; extinct forms representing modern developmental transitions; lines to be dredged. |
| 1869 | 11 | 220–225 | THE GULF STREAM.—Characteristics of the Atlantic sea-bottom off the coast of the United States.—L. F. Pourtales.<br>Manner of dredging; siliceous formation; green-sand formation. |

### DEEP-SEA SOUNDINGS AND TEMPERATURES.

| | | | |
|---|---|---|---|
| 1854 | 54 | *191–*192 | CRAVEN'S SPECIMEN-BOX for deep-sea bottoms —T. A. Craven.<br>[Sketch 56.] |
| 1857 | 46 | 398 | DEEP-SEA SOUNDING-APPARATUS.—Description of a form proposed and used by B. F. Sands.<br>[Sketch 70.] |
| 1857 | ........ | .......... | BERRYMAN-BROOKE'S DEEP-SEA SOUNDING-APPARATUS.<br>[Sketch 71.] |
| 1858 | 37 | 228–246 | DEEP-SEA SOUNDINGS.—W. P. Trowbridge.<br>Investigation of the laws of motion governing the descent of the weight and line; formulæ of velocity of descent.—Table I, rates of descent and resistance, in pounds, upon the sinker and line, with one and with two 32-pound shot, attached to a line 0.07 of an inch in diameter; II, same, with 96 and 126 pound weights—deep-sea line; III, influence of different lengths of line moving with the same velocity; ratios of lengths to ratio of resistances; VII, comparison of resistances upon the same lengths of lines of different diameters, moving at the same velocity; VI, influence of lengths at different depths; VIII, same, continued; IX, rates of descent, velocity, resistance to sinker and line, and weight of line in water, from observations made by Joseph Dayman; diameter of line, 2 inches; weight, 96 pounds; specific gravity, 1.3.—[Sketch 38.]—[Errata, p. 235: 1858, p. xxi.] |
| 1858 | 39 | 248–250 | ANALYSIS, MICROSCOPICAL, of specimens of bottom taken in sounding.—L. F. Pourtales.<br>Green and ochraceous incrustation of *Foraminifera*, and jet tint of specimens. |
| 1859 | 34 | 359–364 | DEEP-SEA SOUNDING-APPARATUS.—Description of a form devised by W. P. Trowbridge, and explanation of its method and use.<br>[Sketch 39.]—[Errata, 359, 1860, p. xx.] |
| 1861 | 11 | 135–139 | SOUNDING-APPARATUS AND LOG.—W. P. Trowbridge.<br>Results obtained with an instrument devised by him. |
| 1866 | 5 | 35–44 | FLORIDA STRAITS.—H. Mitchell.<br>Report on soundings; northern approach; southern approach; difficulties in the way of laying a telegraph cable; remarks upon lines and leads; table of soundings across the Straits of Florida, from Sand Key to El Moro, 1866.—[Sketch 17.] |
| 1866 | 5 | 139 | BERRYMAN APPARATUS; rates of outrun of line.—(*See* 1857, specimen sounding, Sketch 71.) |
| 1868 | 12 | 168–170 | REPORT UPON DREDGINGS NEAR THE FLORIDA REEF.—L. F. Pourtales.<br>Organic specimens; corals, echinoderms, brachiopods, &c. |
| 1874 | 14 | 152 | DEVICE for detaching from a line the heavy weight requisite in deep-sea soundings.—[Sketch No. 23.]—Lieut. Com. C. D. Sigsbee. |
| 1876 | 23 | 407–409 | LIST OF PUBLICATIONS relating to the deep-sea investigations carried on in the vicinity of the coasts of the United States under the auspices of the Coast Survey. |
| 1879 | 6 | 95–102 | DREDGING OPERATIONS in the Caribbean Sea.—[With two maps.]—Alexander Agassiz. |
| 1880 | †16 | 297–340 | BERING SEA.—W. H. Dall.<br>Report on the currents and temperatures; and also those of the adjacent waters; sources of information; surface temperature; tables of temperatures; pack ice; summer temperatures; the Kuro Siwo and its extensions; table of North Pacific Sea temperatures; comparison of sea temperatures from observations by the Challenger, 1873 and 1875; currents of Bering Sea; observations of the Tuscarora and Venus; those of Krusenstern, 1804–1806; notes by whalers and others; table of temperatures; of currents; observations off the coast of Asia; in the Arctic in general; in the vicinity of Point Barrow.<br>SUPPLEMENTARY NOTE.—Additional observations in the Arctic Sea; boundary line between the territory of the United States and Russia; diagrams of surface and vertical isotherms; chart of currents. |

## TERRESTRIAL MAGNETISM.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1845 | 3 | 41–43 | REMARKS on the currents in Mississippi Sound and changes in the magnetic variation.—F. H. Gerdes. |
| 1854 | 30 | *37–*40 | (1853–'54.)—Page 39: Reference to instruments used, &c., in California.—W. T. Trowbridge. |
| 1854 | 43 | *142–*145 | (1844–'45.)—TABLE OF MAGNETIC DECLINATION.—G. W. Dean.<br>Results of Coast Survey magnetic observations at 136 stations along the coast of the United States.—[Errata, p. 144, 145: 1855, p. xix.] |
| 1854 | 44 | *146 | MERIDIAN-LINES.—Report of Assistant G. W. Dean on the establishment of meridian-lines at Petersburg, Va., and Raleigh and Wilmington, N. C. |
| 1855 | 47 | 295–306 | (1844–'55.)—TABLE OF MAGNETIC DECLINATION, in geographical order, from Coast Survey observations; with notes by A. D. Bache and J. E. Hilgard.<br>Discussion of magnetic declination: 1, northern part of Gulf of Mexico; 2, Atlantic coast; 3, Pacific coast.—[Sketch 56.] |
| 1855 | 48 | 306–337 | (1717–1855.)—SECULAR VARIATION OF MAGNETIC DECLINATIONS.—C. A. Schott.<br>Discussion of the secular change in the magnetic declinations on the Atlantic and part of the Gulf coasts of the United States: Providence, R. I.; Hatborough, Pa.; Philadelphia, Pa.; Boston, Mass.; Cambridge, Mass.; New Haven, Conn.; New York, N. Y.; Charleston, S. C.; Mobile, Ala.; Havana, Cuba; Burlington, Vt.; Chesterfield, N. H.; Salem, Mass.; Nantucket, Mass.; Albany, N. Y.; Washington, D. C.; Pensacola, Fla.—[Sketch 51.]—[Errata, pp. 314, 335: 1855, p. xviii.] |
| 1855 | 49 | 337 | (1855.)—MAGNETIC OBSERVATIONS.—C. A. Schott.<br>Results for declination, dip, and horizontal intensity, on sixteen eastern stations, July to September, 1855. |
| 1856 | 28 | 209–225 | (1839–1855.)—TERRESTRIAL MAGNETISM.—Discussion relative to its distribution in the United States.—A. D. Bache and J. E. Hilgard.<br>Methods and sources used; corrections for secular variations; construction of maps (Sketches 61 and 62); comparison of maps for declination, dip, and intensity; supplementary note (Mexican observations); Table I, Atlantic, Gulf, and Pacific sections; II, near parallel 35°, by J. C. Ives, Whipple's expedition; III, from various new sources—lakes, territories, Panama; IV, residual difference between the Coast Survey observations, reduced to 1850, and the values obtained from the accompanying map.—[Sketches 61 and 62.] |
| 1856 | 29 | 226 | MAGNETIC OBSERVATIONS.—C. A. Schott.<br>Methods used in his observations of the present year; magnet H. |
| 1856 | 30 | 227 | (1856.)—MAGNETIC ELEMENTS.—C. A. Schott.<br>Results of his observations for declination, dip, and intensity at stations in Delaware, Maryland, and Virginia. |
| 1856 | 31 | 228–235 | (1792–1855.)—SECULAR CHANGE OF DECLINATION; Western coast.—C. A. Schott.<br>List of magnetic declinations observed on the western coast from the earliest to the present ones, arranged in order of geographical latitudes.—Annual change: 1, San Diego; 2, Monterey; 3, San Francisco; 4 Cape Mendocino; 5, Cape Disappointment.—Recapitulation of results for secular change. |
| 1856 | 32 | 235–245 | (1780–1855.)—SECULAR CHANGE OF INCLINATION; Atlantic coast.—C. A. Schott.<br>Toronto, Canada; Albany and Greenbush, N. Y.; Cambridge, Mass.; Providence, R. I.; West Point and Cold Spring, N. Y.; New Haven, Conn.; New York, N. Y.; Philadelphia, Pa.; Washington, D. C.; Baltimore, Md.; recapitulation of results.—Table I, geographical positions and number of dip-observations; II, formula for each station; III, probable error, epoch of minimum dip and annual variation in current year.—[Sketch 63.] |
| 1856 | 33 | 246–249 | (1790–1855.)—SECULAR CHANGE OF INCLINATION; Western coast.—Approximate determination of the secular change of inclination.—C. A. Schott.<br>Table of observations made up to the present time; deductions therefrom.—1, San Diego; 2, San Pedro; 5, Monterey; 6, San Francisco; 8, Fort Vancouver; 10, Cape Disappointment. |
| 1857 | 32 | 334–342 | MAGNETISM.—Gradual loss of magnetic momentum in the Coast Survey magnets.—C. A. Schott.<br>Account of magnets: S 8, C 32, C 9, D, C 6, H, and Smithsonian magnet used in 1855.—Table: recapitulation of values for magnets severally, and discussion.—[Sketch 68.] |
| 1858 | 24 | 191–192 | (1856–1858.)—MAGNETIC ELEMENTS.—Continuation. |
| 1858 | 25 | 192–195 | (1680–1850.)—SECULAR VARIATION of magnetic declination at Hatborough, Pa.—C. A. Schott.<br>Discussion and development of an intermediate period.—Table of declinations from 1680 to 1850.—Diagram.—[Errata, p. 193: 1858, p. xxi.] |
| 1858 | 26 | 195–197 | (1809–1857.)—SECULAR VARIATION AT WASHINGTON, D. C.—C. A. Schott.<br>Declination from 1809 to 1857.—Dip from 1839 to 1858. |
| 1859 | 16 | 172–175 | (1858.)—VARIATION OF THE COMPASS.—General table for the use of navigators.—[Sketch 38.] |
| 1859 | 23 | 296 | (1859.)—DECLINATION, DIP, AND INTENSITY.—C. A. Schott.<br>Results of observations made by him in Canada, Maine, New Hampshire, Vermont, Massachusetts, and Connecticut.—Foot-note on disturbances. |
| 1859 | 24 | 296–305 | (1680–1860.)—SECULAR CHANGE IN DECLINATION.—C. A. Schott.<br>Variation of the needle on the coasts of the United States for every tenth year since 1680; formulas expressing secular change, used for calculating the tabular values for Group I, stations between Portland, Me., and Williamsburg, Va., with table of observations made between 1680 and 1860; for Group II, southern stations and western coast.—Record of all observed declinations made use of in the above paper not heretofore published in the Coast Survey Reports. |
| 1860 | 21 | 269–274 | (1860.)—ECLIPSE at Auleziavik; suspension of vibrations during totality. |

## TERRESTRIAL MAGNETISM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1860 | 25 | 324–326 | SOLAR SPOTS.—Report of Assistant C. A. Schott on the results of observations made during the first seven months of the year 1860. |
| 1860 | 26 | 326–349 | KEY WEST STATION.—Description of instruments and plan of magnetic observatory; with results.—W. P. Trowbridge.<br>Declinometer, recording cylinder, and clock; vertical-force magnetometer; adjustments; mean daily range of temperature for each month, 1851, 1852, and monthly range for four years; mean monthly temperature for fourteen years; lamps; scale-measurements; temperature coefficients of the horizontal and vertical forces of magnets; photographic arrangements; magnet H—axis and intensity; dip; scale-values for intensity-magnets—tables and computation; experiments for temperature coefficients of horizontal-force magnet, with hot water and ice.—[Sketches 23 and 24.] |
| 1860 | 27 | 350–351 | EASTPORT STATION, MAINE.—General description of magnetic station.—L. F. Pourtales. |
| 1860 | 28 | 351–352 | DECLINATION, DIP, AND INTENSITY at various stations (supplementary to 1856, p. 227, and 1858, p. 191). |
| 1860 | 29 | 352 | DECLINATION, DIP, AND INTENSITY, determined in 1860 on the coasts of Massachusetts, Long Island, and New Jersey.—C. A. Schott. |
| 1861 | 22 | 242–251 | SECULAR CHANGE OF INTENSITY.—C. A. Schott.<br>Discussion of observations made on the Atlantic, Gulf, and Pacific coasts of the United States; intensity-statistics; notes; table of annual change for Atlantic and Pacific groups. |
| 1861 | 23 | 251–256 | NEW DISCUSSION of the distribution of the magnetic declination on the coast of the Gulf of Mexico, with a chart of the isogonic curves, for 1860.—C. A. Schott. |
| 1861 | 24 | 256–259 | NEW DISCUSSION of the distribution of the magnetic declination on the coast of Virginia, South Carolina, and Georgia, with a chart of the isogonic curves for 1860.—C. A. Schott. |
| 1861 | 25 | 259–261 | SOLAR SPOTS.—Abstract of observations made at the Coast Survey Office.—C. A. Schott. |
| 1862 | 18 | 212 | RESULTS for declination, dip, and horizontal intensity in Pennsylvania and District of Columbia.—C. A. Schott. |
| 1862 | 19 | 212–229 | MAGNETIC SURVEY of Pennsylvania and parts of adjacent States from 1834 to 1862.—A. D. Bache.<br>Declinations observed by him in 1840 and 1841; tabular comparison of secular changes in 1840, 1841, and 1862; chronometric results for longitude; geographical positions; distribution of declination for 1842.0; general table of results referred to common epoch, 1842.0; comparison of observed and computed values; dip, distribution of, and isoclinal lines for 1842, groups 1 to 4; correction to epoch; comparison of observed and computed dip; horizontal intensity and isodynamic lines for 1842; tabular formation of groups for the analytical expression of the distribution of horizontal force referred to 1842.0; comparison of observed and hypothetical computed values; representation of the total force.—[Sketch 47.] |
| 1862 | 20 | 230–231 | DECLINATION, DIP, AND INTENSITY at various stations (supplementary to list 1860, pp. 351–352). |
| 1862 | 21 | 231–232 | SOLAR SPOTS.—Abstract of observations made at the Coast Survey Office.—C. A. Schott.<br>Supplementary to the preceding report. |
| 1862 | †22 | 232–235 | BESSEL'S PERIODIC FUNCTIONS developed for periods frequently occurring in magnetic and meteorological investigations, with examples.—C. A. Schott. |
| 1862 | 23 | 236–238 | DIPPING-NEEDLE.—Description of a new form of axis changeable in position.—J. E. Hilgard. |
| 1863 | 22 | 204 | DECLINATION, DIP, AND INTENSITY, from observations, by C. A. Schott and G. W. Dean, in Maine, Connecticut, and the District of Columbia—discussed. |
| 1863 | 23 | 205 | INDUCTION-TIME IN RELAY-MAGNETS.—Report on experiments made by Assistant G. W. Dean to determine their relative power. |
| 1864 | 18 | 205–206 | GIRARD COLLEGE OBSERVATIONS.—Index to discussion by A. D. Bache.—(*See* Magnetic elements; discussed.) |
| 1859 | 22 | 278–295 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 37.]—[Errata, pp. 279, 280, 293: 1860, p. XX.]<br>Part I. Investigation of the eleven-year period in the amplitude of the solar-diurnal variation and of the disturbances of the magnetic declination. |
|  |  | 278 | Introduction. |
|  |  | 279 | Separation of disturbances and establishment of normal readings of the declinometer. |
|  |  | 285 | Analytical expressions of the regular solar diurnal variation of the declination. |
|  |  | 286 | Inequality of the amplitude due to the eleven (or ten) year period. |
|  |  | 287 | Discussion of the number of disturbances of the declination; their annual inequality. |
|  |  | 290 | Diurnal inequality of the number of disturbances of the declination. |
|  |  | 290 | Deflections by disturbances; their mean annual amount; effect of the eleven (or ten) year period. |
|  |  | 292 | Deflections by disturbances; their mean diurnal amount. |
|  |  | 295 | Connection of the frequency of the solar spots with the changes in the amplitude of the diurnal variation of the declination. |
| 1860 | 23 | 293–309 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.<br>Part II. Investigation of the solar-diurnal variation in the magnetic variation, and its annual inequality. |
|  |  | 293 | Investigation of the solar diurnal variation of the declination. |
|  |  | 302 | Its semi-annual inequality. |
|  |  | 303 | Analytical and graphical exhibition of the solar diurnal variation for each month, summer, winter, and year. |
|  |  | 307 | Maxima and minima, and times of average value of the declination; diurnal range. |
|  |  | 309 | Annual variation of the declination. |

## TERRESTRIAL MAGNETISM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1860 | 24 | 312–324 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache. |
| | | | Part III. Investigation of the influence of the moon on the magnetic declination. |
| | | 312 | Lunar influence on the magnetic declination; tabulation of results according to the moon's hour-angle. |
| | | 318 | Comparison of lunar diurnal variation for three epochs. |
| | | 319 | Resulting lunar diurnal variation. |
| | | 321 | Inequality in the lunar diurnal variation. |
| | | 324 | Investigation of deflections depending upon lunar phases; variation in declination and in parallax. |
| 1862 | 15 | 161–185 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 48.]—[Errata, pp. 178, 182: 1862, p, IV.] |
| | | | Part IV. Investigation of the eleven (or ten) year period and of the disturbances of the horizontal component of the magnetic force. |
| | | 161 | Instrumental notice. |
| | | 162 | Correction of readings for changes of temperature; scale-values. |
| | | 169 | Correction for progressive instrumental change; hourly normals for each month. |
| | | 173 | Horizontal intensity, absolute value; effect of the loss of magnetism of the bar; secular change. |
| | | 174 | Separation of the larger disturbances. |
| | | 175 | Corrected normals. |
| | | 178 | Investigation of the eleven (or ten) year period, from changes in the amplitude of the solar diurnal variation. |
| | | 180 | Eleven (or ten) year inequality, as indicated by the disturbances. |
| | | 182 | Analysis of the disturbances; annual and diurnal variation. |
| | | 185 | Classification of disturbances according to their magnitude. |
| 1862 | 16 | 186–200 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 48.] |
| | | | Part V. Investigation of the solar-diurnal variation and of the annual inequality of the horizontal component of the magnetic force. |
| | | 186 | Preparation of hourly normals for each month. |
| | | 193 | Regular solar diurnal variation. |
| | | 194 | Semi-annual inequality in the diurnal variation. |
| | | 195 | Analysis of the solar diurnal variation. |
| | | 198 | Epochs of maxima and minima; amplitude; epochs of average value. |
| | | 200 | Annual variation of the force. |
| 1862 | 17 | 202–212 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache. |
| | | | Part VI. Investigation of the influence of the moon on the magnetic horizontal force. |
| | | 202 | Number of observations for lunar discussion and their distribution according to western and eastern hour-angles of the moon; differences from monthly normals, arranged for moon's hour-angles. |
| | | 206 | Lunar diurnal variation for two periods. |
| | | 207 | Lunar diurnal variation in summer and winter. |
| | | 209 | Analysis of the lunar diurnal variation. |
| | | 210 | Investigation of the horizontal force in reference to lunar phases. |
| | | 211 | Influence of the moon's changes of declination. |
| | | 212 | Influence of the moon's changes of distance. |
| 1863 | 19 | 156–183 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 30.] |
| | | | Part VII. Investigation of the eleven-year period and of the disturbances of the vertical component of the magnetic force, with a supplement on the effect of auroral lights. |
| | | 156 | Instrumental notice. |
| | | 157 | Determination of the effect of changes of temperature; scale-values; reduction of observations to a uniform temperature. |
| | | 164 | Recognition and separation of the larger disturbances. |
| | | 168 | Investigation of the eleven (or ten) year period, in the amplitude of the diurnal variation. |
| | | 171 | Investigation of the eleven (or ten) year period in the disturbances, and their general analysis. |
| | | 172 | Annual inequality in the number and amount of disturbances. |
| | | 174 | Diurnal inequality of the disturbances. |
| | | 177 | Classification of the disturbances according to their magnitude. |
| | | 178–183 | Appendix: effect of the aurora borealis on the declination, the horizontal and vertical force. |

## TERRESTRIAL MAGNETISM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1863 | 20 | 183–195 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 30.] |
| | | | Part VIII. Investigation of the solar-diurnal variation and of the annual irregularity of the vertical component of the magnetic force. |
| | | 183 | Preparation of hourly normals for each month and year. |
| | | 189 | Regular solar diurnal variation. |
| | | 190 | Semi-annual inequality of the diurnal variation. |
| | | 190 | Analysis of the diurnal variation. |
| | | 193 | Maxima and minima; ranges; epochs of average force. |
| | | 195 | Annual inequality of the vertical force. |
| 1863 | 21 | 196–204 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache. |
| | | | Part IX. Investigation of the influence of the moon on the magnetic vertical force. |
| | | 196 | Number of observations for lunar discussion; distribution according to eastern and western hour-angles; differences from monthly normals, arranged for moon's hour-angles. |
| | | 201 | Lunar diurnal variation in summer and winter. |
| | | 202 | Analysis of the lunar diurnal variation of the vertical force. |
| | | 204 | Lunar effect upon inclination and total force. |
| 1864 | 16 | 183–192 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache. |
| | | | Part X. Analysis of the disturbances of the dip and total force. |
| | | 183 | Formation of table of disturbances of the two component parts and their combination for dip and total force. |
| | | 184 | Analysis of disturbances of the inclination. |
| | | 185 | The annual inequalities in amount and number; eleven (or ten) year inequality. |
| | | 186 | Diurnal inequalities, in amount and number. |
| | | 187 | Classification of disturbances in dip, according to their magnitude. |
| | | 187 | Analysis of disturbances of total force. |
| | | 188 | Their annual inequalities, in amount and number; eleven (or ten) year inequality. |
| | | 189 | Diurnal inequalities, in amount and number. |
| | | 190 | Classification of disturbances in total force. |
| 1864 | 17 | 191–198 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache.—[Sketch 38.] |
| | | | Part XI. Solar-diurnal variation and annual inequality of the inclination and total force. |
| | | 193 | Combination of the diurnal normals of the two components for dip and total force. |
| | | 193 | Solar diurnal variation of the inclination. |
| | | 194 | Its semi-annual inequality. |
| | | 194 | Analysis of the solar diurnal variation of the dip. |
| | | 195 | Maxima and minima; ranges and epochs of average value. |
| | | 196 | Solar diurnal variation of the total force. |
| | | 196 | Its semi-annual inequality. |
| | | 197 | Analysis of the solar diurnal variation of the total force. |
| | | 198 | Annual inequality of the dip and total force. |
| 1864 | 18 | 199–206 | DISCUSSION OF THE MAGNETIC AND METEOROLOGICAL OBSERVATIONS made at the Girard College Observatory, Philadelphia, in 1840, 1841, 1842, 1843, 1844, and 1845.—A. D. Bache. |
| | | | Part XII. Discussion of the magnetic inclination and table of absolute values of the declination, inclination, and intensity between 1841 and 1845. |
| | | 199 | Discussion of the magnetic inclination; introductory notice. |
| | | 200 | Abstract of observations of dip; monthly means. |
| | | 203 | Collection of dip-observations at Philadelphia. |
| | | 203–204 | Analytical expression of secular change of dip normal; absolute values of the magnetic declination, dip, horizontal, vertical and total force for five epochs, and the mean epoch, January, 1843. |
| 1864 | 19 | 207–210 | DECLINATION, DIP, AND INTENSITY, as derived from observations made by J. N. Nicollet in the Southern States between 1832 and 1836. |
| 1864 | 20 | 211–220 | EDUCTION-TIME OF RELAY-MAGNETS, deduced from experiments.—G. W. Dean. |
| 1865 | 18 | 166–174 | RESULTS of magnetic observations made at Eastport, Me., between 1860 and 1864. |
| | | | Declination; diurnal range of; annual inequality (diagram); epochs of greatest diurnal deflection; mean monthly values of declination between August, 1860, and July, 1864; annual effect of the secular change; annual inequality of the declination; same at Toronto; comparative curve.—[Sketch 29 (theodolite magnetometer).] |
| 1865 | 19 | 174–176 | REPORT on the distribution of the magnetic declination on the coast and parts of the interior of the United States.—C. A. Schott. |
| | | | Isogonic chart for 1870.—[Sketches 27 and 28.] |

## TERRESTRIAL MAGNETISM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1869 | 9 | 199–207 | Report on the results from the observations made at the magnetic observatory on Capitol Hill, Washington, D. C., between 1867 and 1869.—C. A. Schott.<br>Magnetic instruments; scheme of observing; instrumental constants; results; declination on Capitol Hill; turning-epochs; dip; horizontal force; tabular synopsis of magnetic elements observed in the District of Columbia. |
| 1870 | 14 | 107–110 | New investigation of the secular changes in the *declination, dip, and intensity* of the magnetic force at Washington, D. C.—C. A. Schott. |
| 1870 | 15 | 111–114 | Results of observations for *daily variation* of the magnetic declination, made at Fort Steilacoom, Washington Territory, in 1866, and at Camp Date Creek, Arizona, in 1867, by David Walker, Acting Assistant Surgeon U. S. A., and discussed and reported by Assistant C. A. Schott. |
| 1872 | †14 | 235–254 | Magnetic observations by means of portable instruments.—C. A. Schott.<br>1, determination of the magnetic declination; adjustment of the declinometer; example of scale-reading; magnetic declination; example; 2, absolute and relative measures of the magnetic force; the magnetometer; observations of deflections; horizontal intensity; deflections; form 1; magnetometer with attached theodolite; deflecting magnet in the magnetic prime vertical; form 2; theodolite-magnetometer; deflecting and deflected magnets at right-angles to each other; observations of oscillations; example; calculation; example of observation of deflections; 3, determination of the magnetic declination; reversal of poles of dipping-needles; magnetic dip; specimen of record for finding magnetic meridian; magnetic dip; computation; concluding remarks.<br>Appendix.—Ordinary adjustments of the theodolite. |
| 1874 | †8 | 72–108 | Secular change of magnetic declination in the United States and other parts of North America: new discussion.—C. A. Schott.<br>Collection of magnetic declinations, Halifax, Nova Scotia; Quebec, Canada; York Factory, Hudson Bay; Portland, Me.; Burlington, Rutland, Vt.; Portsmouth, N. H.; Newburyport, Salem, Boston, Cambridge, Nantucket, Mass.; Providence, R. I.; Hartford, New Haven, Conn.; Albany, Oxford, Buffalo, N. Y.; Erie, Pa.; Cleveland, Ohio; Detroit, Mich.; New York and vicinity, N. Y.; Hatborough, Philadelphia, Pa.; Washington, D. C.; Cape Henry, Va.; Charleston, S. C.; Savannah, Ga.; Key West, Fla.; Havana, Cuba; Kingston, Jamaica; New Orleans, La.; Vera Cruz, City of Mexico, Acapulco, San Blas, Mexico; Panama, New Granada; San Diego, Monterey, Point Pinos, San Francisco, Cal.; Cape Disappointment, W. T.; Sitka, Captain's Harbor, Unalashka Island, Alaska; Eastport, Me.; Hanover, Chesterfield, N. H.; Toronto, Canada; Baltimore, Md.; Williamsburg, Va.; New Berne, N. C.; Mobile, Florence, Ala.; Saint Louis, Mo.; Cape Mendocino, Cal.; Nootka, Vancouver's Island; Petropaulovski, Kamtchatka; table of empirical expressions for magnetic declination; comparison of magnetic declination observed and computed; table, number of observations at each place; table of decennial values of the magnetic declination. |
| 1874 | †9 | 109–130 | Magnetic observations, Key West, Fla.—C. A. Schott.<br>Monthly results for magnetic declination, 1860–1866; annual effect of the secular change of declination; annual variation of the declination; observed annual variation of the declination at stations near the Atlantic seaboard; monthly values for magnetic dip at Key West; annual effect of the secular change in the dip; monthly values for horizontal intensity at Key West; annual effect of the secular change in the horizontal intensity; annual variation in the horizontal intensity; general table of results from absolute measures of the magnetic declination, dip, and intensity; differential measures of changes in magnetic declination from Brooke's automatic registration at Key West, 1860–1866; monthly means of hourly readings from the photographic traces of the fixed declination at Key West; recapitulation of monthly means of declinometer readings; permanency in the line of detorsion in the suspension-skein; discussion of the disturbances of the magnetic declination; monthly normals of hourly readings of the declinometer at Key West; mean monthly normals of hourly readings from observations extending over six years; number of disturbances during six successive years; distribution of disturbances in the yearly period; in the daily period; average magnitude of disturbances during successive years; in the yearly period; in the daily period; solar diurnal variation in the magnetic declination at Key West for the epoch 1863.3; the same between 1860 and 1866; the same at Philadelphia for the epoch 1842.5; diagram; characteristic features of the daily variation; eleven-year inequality in the solar diurnal variation; mean annual normals of hourly readings of the declinometer for six years, 1860–1866, at Key West; mean annual normal deflections at each hour. |
| 1875 | †16 | 254–278 | Terrestrial magnetism.—C. A. Schott.<br>Instructions for magnetical observations.—(Reprinted from Appendix No. 14, Report of 1872.)<br>1, determination of the magnetic declination; sketch; adjustment of the declinometer; example of scale-reading; magnetic declination; ordinary adjustments of the theodolite; diagram; example of record and reduction; solar diurnal variation of declination at Toronto, Canada, Philadelphia, and Key West; 2, determination of the magnetic inclination; reversal of the poles of dipping-needles; diagram No. 29, of dip-circle; 29 B, dip-circle; magnetic dip; specimen of record for finding magnetic meridian; 3, absolute and relative measures of the magnetic force; the magnetometer; observations of deflections; forms 1, 2; observations of oscillations; forms; example to observations of deflections for value of *q* of magnet H. |
| 1876 | †21 | 400 | Chart of magnetic declination in the United States, 1875.—J. E. Hilgard. |
| 1877 | 7 | 96–97 | Magnetic observatory at Madison, Wis.—C. A. Schott. |

## TERRESTRIAL MAGNETISM—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1879 | 19 | 124–174 | Secular change of magnetic declination in the United States and at some foreign stations.—(Fourth edition, June, 1881.)—C. A. Schott.—(A third edition was published separately June, 1879.)<br>Magnetic declination, definition; solar diurnal variation; annual variation; lunar inequalities; magnetic disturbances; historical note; the needle used among the Chinese and Norwegians; the declination; isogonic charts; secular variation of the declination; analytical expression of the secular change of the declination; collection of magnetic declination for the discussion of the secular change; Paris, France; Halifax, Nova Scotia; Quebec, Montreal, Canada; York Factory, Hudson Bay; Portland, Me.; Burlington, Rutland, Vt.; Portsmouth, N. H.; Newburyport, Salem, Boston, Cambridge, Nantucket, Mass.; Providence, R. I.; Hartford, New Haven, Conn.; Albany, Oxford, Buffalo, N. Y.; Toronto, Canada; Erie, Pa.; Cleveland, Ohio; Detroit, Mich.; Saint Louis, Mo.; New York and vicinity, N. Y.; Philadelphia, Harrisburg, Pa.; Baltimore, Md.; Washington, D. C.; Cape Henry, Va.; Savannah, Ga.; Key West, Fla.; Havana, Cuba; Kingston, Jamaica; Panama, New Grenada; Rio Janeiro, Brazil; Mobile, Ala.; New Orleans, La.; Vera Cruz, City of Mexico, Acapulco, San Blas, Mexico; Magdalena Bay, Lower California; San Diego, Monterey, Point Pinos, San Francisco, Cal.; Cape Disappointment, W. T.; Kailua, Hiio, and Kealakekua Bays, Owhyhee, Sandwich Islands; Honolulu, Oahu, Sandwich Islands; Sitka, Alaska; Captain's Harbor, Unalashka; Petropaulovski, Kamtchatka; St. John's, Newfoundland; Eastport, Me.; Hanover, Chesterfield, N. H.; Sault Ste. Marie, Grand Haven, Mich.; Williamsburg, Va.; New Berne, N. C.; Florence, Ala.; Bermuda Islands; San Antonio, Tex.; Omaha, Nebr.; Council Bluffs, Iowa; Salt Lake City, Utah; Cape Mendocino, Cal.; Port Townsend, W. T.; Nee-ah Bay, W. T.; Nootka, Vancouver Island.—Table I, formula for magnetic declination at various places; Table II, comparison of observed and computed magnetic declinations; Sketch No. 38; Table III, number of observations; apparent probable error of observation; Sketch No. 37; Sketch No. 39; Table IV, decennial values of the magnetic declination computed from preceding equations. |
| 1880 | †19 | 412–417 | Variation of the compass off the Bahama Islands at the time of the landfall of Columbus in 1492.—C. A. Schott.<br>Remarks on the early use of the compass; at the time of Columbus; reckoning time; notes on the voyages of Columbus; line of no variation; corrections to the agonic line; track of Columbus across the Atlantic in 1492 in tabular form; conclusions.—[Sketch No. 84.] |

## DRAWING, ENGRAVING, AND ELECTROTYPING.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1851 | 55 | 541–553 | Electrotyping operations of the Coast Survey.—G. Mathiot.<br>Adhesion of deposit to matrix; actions in the electrolytic solution; laboratory apparatus; manipulation. [Sketch 58.] |
| 1852 | 21 | 108–111 | On lithographic-transfer printing.—J. J. Stevens. |
| 1853 | 36 | *90–*93 | Notes on lithography and lithographic transfer.—E. B. Hunt. |
| 1854 | 31 | *54–*57 | On electrotype operations and chemiglyphic experiments.—G. Mathiot. |
| 1854 | 56 | *193–*201 | Mathiot's self-sustaining battery.—G. Mathiot.<br>Its principles and workings.—[Errata, pp. 194, 198: 1855, p. xix.] |
| 1854 | 57 | *201–*212 | Art and practice of engraving.—E. B. Hunt.<br>Coast Survey engraving; its office, organization, and history.—[Errata, p. 204; *see* Index of errata.] |
| 1855 | 61 | 366–368 | Galvanic experiment.—G. Mathiot.<br>Time required to produce the maximum intensity of a voltaic current. |
| 1855 | 62 | 369 | Electrotype art.—G. Mathiot.<br>Improved method for joining detached plates by electrotyping. |
| 1855 | 63 | 370–373 | Mathiot's branch circuit galvanometer.—G. Mathiot.<br>On a method of measuring galvanic currents of great quantity. |
| 1856 | 62 | 316–317 | Electrotypes.—G. Mathiot.<br>On the result of experiments made in printing from thin plates. |
| 1860 | 20 | 216–229 | Topographical and Hydrographical delineations.—H. L. Whiting.<br>On the contouring and reduction of maps; on the scale of shades, and on the application of photography in preparing details for the engraver; 1, generalization of contour and other natural features for reduction to 1-80,000 contour; salt-marsh; sand-beaches and sand-hills; woods; fresh marsh; shore-line; low water; 2, hydrographic reductions; 3, reductions by photography; 4, scale of shades; report of E. Hergesheimer. |
| 1860 | 40 | 398–399 | Dividers for tidal curves.<br>Description of form invented by J. R. Gillis, for graphical decomposition.—[Sketch 40.] |
| 1861 | 15 | 180–181 | Drawing-paper.<br>Results of experiments made on the relative expansion and contraction, under atmospheric changes, of parchment paper and backed antiquarian paper.—[Sketch 31.] |
| 1862 | 27 | 255 | Drawing-paper tested with reference to expansion and contraction under atmospheric changes. |
| 1863 | 24 | 206–207 | Harrison globe-lens.—J. E. Hilgard.<br>On tests made at the Coast Survey Office. |
| 1866 | 20 | 130–138 | Electrotyping operations.—G. Mathiot.<br>Historical; adhesion of deposit to matrix; time and expense of electro-casting; actions in the electrolytic solution; laboratory apparatus; manipulation. |

## DRAWING, ENGRAVING, AND ELECTROTYPING.—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1867 | 5 | 55-56 | THE PANTOGRAPH; its use in engraving.—E. Hergesheimer.<br>[Sketch 27.] |
| 1875 | 6 | 87 | REPORT UPON ELECTROTYPING AND PHOTOGRAPHING.—Dr. A. Zumbrock. |
| 1879 | †11 | 191 | PREPARATION OF STANDARD TOPOGRAPHICAL DRAWING.—E. Hergesheimer.<br>(Plates 42 to 49.) |

## ASTRONOMY.

| | | | |
|---|---|---|---|
| 1849 | 5 | 72–78 | MECHANICAL RECORD OF ASTRONOMICAL OBSERVATIONS.—O. M. Mitchel.<br>His revolving disk; arrangement for recording differences of declination. |
| 1851 | 9 | 137–145 | Report on a new method of recording differences of north polar distances, or declination, by electro-magnetism.—O. M. Mitchel. |
| 1854 | 40 | *122–*127 | SOLAR ECLIPSE, MAY 26, 1854.<br>Observations made at Brooklyn, Long Island, reported by E. Blunt; at Seaton station, Washington, D. C., by C. O. Boutelle; at Roslyn station, near Petersburgh, Va., by L. F. Pourtales; Black Mountain station, Cal., by R. D. Cutts; Benicia, Cal., by Prof. James Nooney; Humboldt Bay, Cal., by G. Davidson. |
| 1855 | 45 | 278–286 | STAR-CATALOGUES.—C. A. Schott.<br>Comparison of star-places given in Rümker's and the Twelve-Year Catalogues.—Table I, comparison of right ascensions; Table II, of north polar distances. |
| 1860 | 21 | 229–275 | SOLAR ECLIPSE, JULY 18, 1860.—Prof. Steph. Alexander.<br>Results of the expedition to Aulezavik Island, Labrador, to observe the eclipse of the 18th of July, 1860; tabular comparison of chronometers: arrangement and programme; description of the telescope employed; synopsis of the observations; times of contacts; same in local mean time (civil reckoning); other observations; reports from special parties; earth-temperature (Aulezavik); atmospherical electricity; icebergs; mirage, &c.; triple rainbow; auroras; table of meteorological observations made during the hours corresponding to the eclipse at Aulezavik, from July 14 to July 23; during the continuance of auroras *passim;* observations with Arago's polariscope; report of photographers; changes of illumination; seamen's observations; winds; magnetic elements; longitude by chronometer.—[Sketch 39.]—[Errata 239, 275: 1860, p. xx.] |
| 1860 | 22 | 275–292 | SOLAR ECLIPSE.—J. M. Gillis.<br>On the results of observations made near Fort Steilacoom, W. T., on the solar eclipse of July 18, 1860; preliminary; table of meteorological observations on Muck Prairie; latitude-observations; time-observations; chronometer errors and rates; longitude; the eclipse; reports from special parties. |
| 1861 | 19 | 232–239 | SOLAR ECLIPSE OF JULY, 1860.—A. D. Bache.<br>Abstract of observations made at Gunstock Mountain, N. H.: 1, dispositions; 2, first contact; 3, positions of spots; I, table of observations, July 17; II, July 18, before; III, during; IV, after the eclipse; 4, occultation of spots; 5, last contact; 6, phenomena.—[Sketch 29.]—[Errata, 232: 1862, front leaf.] |
| 1861 | 20 | 239–241 | SOLAR ECLIPSE OF JULY, 1860.—C. A. Schott.<br>Abstract of observations made at the Coast Survey Office, Washington, D. C.; first contact; last contact; after the eclipse; heliographic position of the spots. |
| 1861 | 21 | 241–242 | SOLAR ECLIPSE OF JULY, 1860.—B. A. Gould.<br>Abstract of observations made at Cambridge, Mass. |
| 1861 | 25 | 259–261 | SOLAR SPOTS.—C. A. Schott.<br>Abstract of observations made at the Coast Survey Office, Washington, D. C.; table from August, 1860, to December, 1861, and monthly relative numbers, compared with Wolf's revised numbers; spotless days.—[Sketch 29.] |
| 1862 | 21 | 231–232 | SOLAR SPOTS.—Continuation of preceding paper. |
| 1865 | 15 | 152–154 | REPORT AND TABLES on the declinations of standard time-stars.—B. A. Gould. |
| 1865 | 16 | 155–159 | REPORT AND TABLES on the positions and proper motions of the four polar stars.—B. A. Gould. |
| 1869 | 7 | 113–115 | LOCAL DEFLECTIONS of the zenith in the vicinity of Washington City.—C. A. Schott. |
| 1869 | †8 | 116–198 | SOLAR ECLIPSE, AUGUST 7, 1869.<br>Reports of observations of the eclipse of the sun on August 7, 1869, made by parties of the Coast Survey at the following stations: Bristol, Tenn., in charge of R. D. Cutts; Shelbyville, Ky., J. Winlock and G. W. Dean; Springfield, Ill., C. A. Schott; Des Moines, Iowa, J. E. Hilgard; Kohklux, Chilkaht River, Alaska, G. Davidson.—General path of the eclipse; contacts; obscuration of solar spots; breaking of sun's limb by lunar asperities; effects of optical inaccuracies; totality; protuberances; corona; emergence; northern and southern limits of totality ascertained; spectroscopic observations; photographic records; reduction of micrometric photograph-measures; deviation of photographed sun's outline from a circle, after corrections; computations of results.—[Sketches 24, 25, and 26.]—[Errata 165.] |
| 1870 | 16 | 115–177 | REPORTS OF OBSERVATIONS upon the solar eclipse of December 22, 1870; extent of the corona as indicated by the spectroscope, p. 150; nature of the coronal envelope and its relation to the sun, p. 152; constitution of the solar atmosphere, p. 153; suggestions with reference to the observation of future eclipses, pp. 154–158. |
| 1870 | 16*a* | 229 | REPORT on the solar eclipse of December 22, 1870.—Prof. Benjamin Peirce, LL. D.—[From report for 1871.] |

## ASTRONOMY—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1871 | †13 | 176–179 | Total solar eclipse, December 22, 1870.—G. W. Dean. |
| | | | Abstract of the chronographic record. |
| 1871 | †14 | 180–184 | Total solar eclipse, December 22, 1870.—C. H. F. Peters. |
| 1871 | 16 | 189–191 | New form of mercurial horizon.—J. Homer Lane. |
| | | | Directions for setting up and using. |
| 1872 | 8 | 75–172 | Reports of the astronomical and meteorological observations made at Sherman, Wy. T.—R. D. Cutts, Charles A. Young. |
| | | | Part I, Report of R. D. Cutts (Sketch No. 18 A). |
| | | | Latitude and longitude of Sherman; terrestrial magnetism; meteorology; Table I, difference of reading of observers; Table II, daily means; diagram 1; Table III, hourly means; diagram 2; Table IV, hourly means; aneroid barometer; solar radiation; Table V, amount of solar radiation; Table VI, solar radiation; altitude of the sun; atmospheric electricity; diagram; Table VIII; altitude of the astronomical station; spirit level; barometer; Tables IX, X, XI; boiling-point apparatus; Table XII, temperature of boiling water at Sherman; Table XIII, height of Long's Peak, &c.; Sherman, its atmosphere and climate; meteorological journal. |
| | | 155 | Part II, Report of Prof. C. A. Young. |
| | | | Spectrum of the chromosphere; catalogue of bright lines in the spectrum of the chromosphere, 1872; table showing the number of coincidences between the bright lines observed in the spectrum of the chromosphere and those in the spectrum of the chemical elements; spectra of sun spots; catalogue of lines affected in the spot-spectrum between B and *b;* solar eruptions and other disturbances. |
| 1872 | 9 | 173–176 | Astronomical observations on the Sierra Nevada.—George Davidson. |
| | | | Description of the country adjacent to the summit; the climate and opportunities for observing; the observations; Polaris, Saturn, Moon, &c. |
| 1873 | †15 | 175 | Errata in the Heis Catalogue of Stars. |
| 1874 | †10 | 131–133 | Transit of Venus, 1769.—C. A. Schott. |
| | | | Results of observations for determining positions occupied in Lower California and at Philadelphia. –[Sketch No. 22.] |
| 1875 | †13 | 222–230 | Transit of Venus, Japan, 1874.—George Davidson. |
| | | | Photographic work; observations at great elevations. |
| 1875 | †14 | 231–248 | Transit of Venus, Chatham Island, 1874.—Edwin Smith. |
| | | | Station; foundation; instruments: [Sketch No. 25]; observations; photography; day of transit; work after the transit; computations and results; latitude observations; mean places of stars observed for latitude; results for latitude; magnetic observations: declination; dip; horizontal intensity; results. |
| 1878 | †6 | 81-87 | Transit of Mercury, Summit Station, Central Pacific Railroad (Sketch No. 27).—B. A. Colonna. |
| | | | First external and internal contacts; second internal and external contacts; extracts from record book, of observations, by B. A. Colonna; diagram; observation of contacts, by J. F. Pratt. |
| 1878 | †7 | 88-91 | Transit of Mercury, Washington, D. C.—C. A. Schott. |
| | | | Observations by R. D. Cutts; William Eimbeck; O. H. Tittmann. |

## MATHEMATICS.

| | | | |
|---|---|---|---|
| 1854 | 33 | 63–70 | Computation of triangulation.—Comparison of the reduction of horizontal angles by the methods of "dependent directions" and of "dependent angular quantities" by the method of least squares.—A. D. Bache. |
| | | | [Sketch 58.]—[Errata, 65, 70, 72, 75, 78, 79, 91, 94: 1855, p. xix.] |
| | | 70–86 | Adjustment of horizontal angles.—C. A. Schott. |
| | | 86–95 | Probable error of observation, derived from observations of horizontal angles at any single station and depending on directions —C. A. Schott. |
| 1854 | 41 | 131–138 | Benjamin Peirce's criterion for the rejection of doubtful observations. – B. A. Gould. |
| | | | [Errata, p. *138.] |
| 1855 | 40 | 255–264 | Normal equations.—C. A. Schott. |
| | | | Solution of normal equations by indirect elimination. |
| 1856 | 59 | 307–308 | Probable error.—Article from "Astronomische Nachrichten, No. 1034," translated by C. A. Schott. |
| | | | Determination of the probable error of an observation by the differences of their observations from their arithmetical mean. |
| 1860 | 36 | 361-391 | Formulæ for computing latitudes, longitudes, and azimuths, with an example as used in the Coast Survey Office, and tables for each minute of latitude from 23° to 50°. |
| 1860 | 37 | 392–396 | Cauchy's interpolation-formulæ; with remarks by C. A. Schott. |
| 1864 | 13 | 116–119 | Problem in geodesy.—Determining a position by angles observed from it on any number of stations. |
| 1864 | 21 | 220–222 | Trajectory of ricochet-shot, notes on.—C. A. Schott. |
| 1864 | 22 | 223 | Ranges of shot from heavy ordnance, remarks on.—C. A. Schott. |
| 1869 | †14 | 235 | Solution of the three-point problem, by determining the point of intersection of a side of the given triangle with a line from the opposite point to the unknown point.—A. Lindenkohl. |
| 1870 | 21 | 200–224 | On the theory of errors of observations.—C. S. Peirce. |

## MATHEMATICS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1875 | †19 | 315–368 | Formulæ and factors for the computation of geodetic latitudes, longitudes, and azimuths.<br>(Errata, pp. 316, 317, 318, 367.) Fig. 1. L, M, Z, forms for primary and secondary triangulation, and inverse solution; tables of factors log A, log B, log C, log D, log E; table of correction to longitude for difference in arc and sine; values of log $\frac{1}{\cos \frac{1}{2}\, d\, L}$; table for referring values of co-efficients A, B, C, D, E, from Bessel's to Clarke's ellipsoid; table of log F; auxiliary tables for converting arcs of the Bessel ellipsoid into arcs of the Clarke ellipsoid; formulæ and table for computing the spherical excess of a triangle; table of log *m*. |
| 1876 | 6 | 81 | A new system of Binary Arithmetic.—Benjamin Peirce. |
| 1876 | †14 | 197–201 | Theory of the economy of research.—C. S. Peirce. |

## MISCELLANEOUS.

| | | | |
|---|---|---|---|
| 1851<br>1866 | 10<br>19 | 145–160<br>120–130 | Florida reefs, keys, and coast.—L. Agassiz.<br>Topography of Florida; mode of formation of the reef; animal life; the keys; coral reefs; ship-channel; the main-land; coast survey; physical changes in the Gulf Stream; changes in ages to come. |
| 1851 | 49 | 526–528 | Columbia River commerce.—W. A. Bartlett. |
| 1851 | 50 | 528–530 | Trinidad, Humboldt, and San Diego Bays.—A. D. Bache.<br>Changes of current, and sailing-directions for San Diego.—[Sketches 6 and 7.] |
| 1851 | 51 | 530–531 | Entrance of Columbia River to Astoria, sailing-directions.—W. P. McArthur. |
| 1853 | 18 | *50–*51 | Climate, soil, and general character of Florida keys.—J. Totten. |
| 1853 | 35 | *89 | Boiler-incrustation.—J. Hewston, jr.<br>Analysis of two specimens of deposit from the boiler of the Coast Survey steamer Hetzel. |
| 1854 | 55 | *192 | Sea-water action on metals.—J. E. Hilgard.<br>On the action of sea-water on metals used in the construction of instruments, and on magnetic needles; Phœnix disaster.—(*See, also,* Terrestrial magnetism.)—[Errata, p. *192, 5 from bottom, word 9, *read* presence.] |
| 1854 | ........ | *230–*285 | Consolidated alphabetical index of the ten annual Coast Survey Reports, from 1844 to 1853, inclusive. E. B. Hunt. |
| 1855 | 26 | 176–185 | Descriptive report of localities on the western coast, from the north end of Rosario Strait, Washington Territory, to the southern boundary of California.—G. Davidson. |
| 1855 | 30 | 193–200 | Coast Survey sailing-directions, catalogue. |
| 1855 | 51 | 342–346 | Earthquake-wave, Pacific Ocean.—A. D. Bache.<br>Notice of earthquake-waves on the western coast of the United States, December 23 and 25, 1854; computation of ocean depth.—[Sketch 50 (J, No. 9).]—[Errata, pp. 342, 345: 1855, p. xviii.] |
| 1855 | 64 | 374–375 | Abstract of a complete historical account of the progress of discovery on the western coast of the United States from the earliest period; compiled, under the direction of the Superintendent, by Dr. J. G. Kohl. |
| 1855 | 65 | 376–398 | Blake's geological report, western coast.—W. P. Blake.<br>Observations on the physical geography and geology of the coast of California, from Bodega Bay to San Diego; physical geography of the mountain ranges adjoining the coast; geology of the principal bays and ports from Point Reyes to San Diego.—[Errata, pp. 379, 380, 382, 387, 388, 392, 394, 395, 396: 1857, p. xviii.] |
| 1856 | 63 | 317–318 | Analysis of sea-water.—Chemical analysis of the water of New York Harbor.—Wolcott Gibbs. |
| 1856 | 64 | 318–319 | Analysis of sea-land.—Wolcott Gibbs.<br>Examination of specimens of sea-soil taken from the base-sites at Cape Florida and Cape Sable. |
| 1856 | 65 | 319–322 | Annals of discovery on the Atlantic coast.—J. G, Kohl.<br>Abstract of a history of the progress of discovery on the Atlantic coast of the United States. |
| 1856 | 66 | 322–324 | Annals of discovery, Gulf of Mexico.—J. G. Kohl.<br>Abstract of a memoir on the discovery and geographical development of the shores of the Gulf of Mexico within the limits of the United States. |
| 1856 | 67 | 325–330 | Index of scientific references.—E. B. Hunt.<br>On the plan adopted and progress made in its preparation. |
| 1856 | 68 | 331–333 | Abbreviations for scientific references.—E. B. Hunt.<br>Suggestions for securing uniformity of designation. |
| 1856 | 70 | 335–340 | Coast Survey steamer Hetzel.—Report on cause of boiler explosion.—[Sketch 67.] |
| 1857 | 36 | 354–358 | Winds on the western coast.—A. D. Bache.<br>Table for deducing from the three daily observations the mean of the day; quantities of wind; tables for Astoria, San Francisco, and San Diego, and special wind-statistics.—[Sketch 66.] |
| 1857 | 51 | 404–414 | Index of scientific references.—E. B. Hunt.<br>Report on progress made toward completion. |
| 1857 | 52 | 414–433 | Western coast annals of maritime discovery and exploration.—J. G. Kohl.<br>Report of the method and scope of a memoir on. |
| 1858 | 40 | 251–270 | Foreign geodetic surveys.—W. P. Trowbridge.<br>Review showing their cost and progress, and other data, for comparison with the results of the United States Coast Survey; trigonometrical surveys of England, Ireland, and Scotland; hydrography of England; analysis of the report of the select committee appointed to consider the ordnance survey of Scotland, &c., 1856; France; India; Russia; Prussia; table of statistics of topographical maps in Europe; recapitulation; marine disasters—United States vessels, 1855, 1856, and 1857; imports, exports, tonnage, &c.; Great Britain, 1852 to 1855; Gulf of Mexico shipping; Florida reef. |

## MISCELLANEOUS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1858 | 41 | 270–273 | Progress of the United States Coast Survey.—W. P. Trowbridge.<br>Ratio of results for consecutive periods of twelve years. |
| 1858 | 44 | 297–458 | Directory for the Pacific coast of the United States.—G. Davidson.<br>Sailing-directions; geographical positions; tide-establishments for San Francisco; rainfall; temperatures; commerce; magnetics; meteorological observations in the Strait of Juan de Fuca, &c.; and geographical positions.—[Errata, p. 359, 381, 429, 442: 1858, p. xxi.] |
| 1860 | 41 | 399–402 | Labrador expedition.—A. Murray.<br>Report of a voyage of steamer Bibb, and remarks on the winds and tides, &c.—(*See* Longitude by eclipse.) |
| 1860 | 42 | 402–408 | Geology of the coast of Labrador —Notes by O. M. Lieber. |
| 1862 | 24 | 238–241 | Earthquake-waves.—A. D. Bache.<br>Reprint of a paper deducing the depth of the Pacific Ocean from the effect of the Simoda earthquake on the tide-gauges in California and Oregon in 1854.—[Sketch 50.] |
| 1862 | 25 | 241–248 | Florida reef: its origin, growth, substructure, and chronology.—E. B. Hunt. |
| 1862 | 39 | 268–430 | Directory for the Pacific coast of the United States.—G. Davidson.<br>Introduction and explanatory remarks; Mexico; California; Oregon; Washington Territory and Vancouver's Island; British Columbia; Puget Sound.—Tide-tables for San Francisco, 311; commercial statistics; meteorological observations, Washington Territory, 416; geographical positions, 418; tide-tables for San Diego, 421; for Astoria, 424; for Port Townsend, 427;—of magnetic declination, 1863, 430.—[Errata, 272, 275, 285, 286, 288, 290, 292, 296, 297, 299, 301, 302, 303, 304, 307, 316, 323, 325, 327, 328, 329, 344, 355, 359, 360, 362, 363, 364, 365, 367, 370, 371, 376, 379, 383, 387, 389, 392, 396, 399, 402, 404, 408: 1866, p. 141.] |
| 1863 | 25 | 207 | Titles of scientific papers by the late Maj. E. B. Hunt, United States Engineers. |
| 1864 | 21 | 220–222 | Trajectory of ricochet-shot, notes on.—C. A. Schott. |
| 1864 | 22 | 223 | Ranges of shot from heavy ordnance, remarks on.—C. A. Schott. |
| 1864 | ........ | 227–308 | Consolidated Index of the ten annual reports from 1854 to 1863, inclusive.—F. F. Nes. |
| 1864 | ........ | 309–315 | Consolidated Index of sketches contained in the ten annual reports from 1854 to 1863, inclusive. |
| 1867 | 17 | 183–186 | Geological and zoological researches; their relation and general interests in the development of coast-features.—L. Agassiz.—(*See, also,* Coasts.) |
| 1867 | 18 | 187–329 | Alaska Territory; coast-features and resources.—G. Davidson.<br>Directory of the coast, 226–261; list of geographical positions, 265–274; aids to navigation, 274–280.—[Sketches 21 to 23.]—[Errata, 289, 22 from bottom, *read* Escholtz Bay.] |
|  | E | 281–290 | Alaska Territory, geology of.—Th. A. Blake.—*Ibid.* |
|  | F | 290–292 | Zoology of Alaska Territory.—W. G. W. Harford. |
|  | G | 293–298 | Vocabularies of the Kodiac, Unalashka, Kenai, and Sitka languages. |
|  | H | 299–317 | Alaska Territory, meteorology of.—A. Kellog. |
|  | L | 318–324 | Botany of Alaska Territory.—A. Kellog. |
|  | N | 325–329 | Vocabulary, Alaskan. |
| 1868 | 14 | 243–259 | Geographical names on the coast of Maine.—Ed. Ballard. |
| 1868 | 15 | 260–277 | Condensed account of M. Hellert's explorations on the Isthmus of Panama; including his special explorations on the Isthmus of Darien, with suggestions for conducting a future survey.—G. Davidson.<br>Explorations; plan for exploration of the river Darien; outfit and duties of engineers; instrumental outfit; use of the heliotrope for communicating messages; form of record of levelings, courses, and distances; rod for leveling, distance, and station-mark for courses; to pack, unpack, and refill steel barometer; methods of ascertaining the discharge of water in any stream. |
| 1869 | 13 | 233–234 | Abstract of a paper read before the National Academy of Sciences, April 16, 1869, on the earthquake wave of August 18, 1868; wave-table.—J. E. Hilgard. |
| 1870 | 11 | 98–99 | Extract from a report relative to a method of determining elevations along the course of a tidal river, without the aid of a leveling-instrument, by setting up graduated staves at such distances apart that the slacks of the tidal currents extend from one to another.—Rule: the difference in the elevations of the zeros of the gauges is equal to one-half the sum of the differences of their readings at the two slack waters.—Henry Mitchell. |
| 1870 | †18 | 180–181 | On the probable effect of extended piers in modifying the channel-facilities of San Francisco Bay, near Yerba Buena Island.—Henry Mitchell. |
| 1870 | †19 | 182–189 | On the phosphate beds of South Carolina.—N. S. Shaler. |
| 1871 | 7 | 100–108 | Meteorological Register, Alaska; 1870-1871.—C. Bryant |
| 1871 | †17 | 193–210 | General Index to professional and scientific papers contained in the Coast Survey Reports from 1851 to 1870. |
| 1871 | 18 | 219 | Errata from 1851 to 1870. |
| 1872 | 11 | 213–221 | Voyage of the steamer Hassler from Boston to San Francisco.—L. F. Pourtales. |
| 1874 | 13 | 148–151 | Economy in coal, as exemplified by the action of compound engines in the steamer Hassler.—Charles E. Emery.<br>General description of the Hassler. |
| 1875 | †10 | 157–188 | Report on Mount Saint Elias, &c., Alaska.—W. H. Dall.<br>I. Historical notes; tabular results of heights, latitudes, and longitudes; general considerations (Sketches 22, 23).<br>II. Discussion of data; reduction of observations, made in 1874, to determine the heights of Mounts Saint Elias, Cook, Crillon, Fairweather, and Vancouver; details of computations. |
| 1876 | 13 | 192–196 | On marine governors.—Charles E. Emery. |

## MISCELLANEOUS—Continued.

| Year. | Appendix. | Pages. | Subject and author. |
|---|---|---|---|
| 1877 | †8 | 98–103 | Alleged changes in the relative elevations of land and sea.—Henry Mitchell.<br>Salt marshes; rocks; Percé Rock; Isle Percé; Green Ledge; Mary Ann Rocks; Bulwark Shoal; Drunken Ledge; Brazil Rock; Jig Rock; Trinity Ledge; Harding's Ledge; Great Ledge. |
| 1879 | 12 | 192–198 | Reconstruction of the dividing engine of the Coast and Geodetic Survey.—G. N. Saegmuller.<br>Table of corrected screw readings for every degree: Table I, residual errors of graduation of theodolites Nos. 5, 118, 133; Table II. |
| 1879 | †14 | 201 | Internal constitution of the earth.—Benjamin Peirce. |
| 1880 | †12 | 145–171 | Blue Clay of the Mississippi River.—George Little.<br>List of authorities; geological history of the Mississippi River; southern drift; bluff or loess; loess or loam; the Mississippi bottoms; Port Hudson; water; soils I to V, analysis; summary; sections 1 to 44; formations, sections, and localities tabulated; Sketch No. 48. |
| 1880 | †18 | 347–411 | Landfall of Columbus.—G. V. Fox.<br>An attempt to solve the problem of the first landing place of Columbus in the New World. Introduction; narrative and discussion; the track of Navarrete; of Varnhagan; of Washington Irving; of Captain Becher; of G. V. Fox; conclusion; summary. Appendix A, p. 401; age of Columbus. Appendix B, p. 401; mile and league of Columbus, Appendix C, p. 403; variation of the compass in 1492; Appendix D, p. 405; the log of Columbus across the Atlantic Ocean, 1492. Appendix E, p. 408; the vessels of Columbus.—[Sketch No. 83.] |

## ADDENDA.

| Year. | Subject and author. |
|---|---|
|  | EARLY PAPERS OF MR. F. R. HASSLER, FIRST SUPERINTENDENT, BEARING ON THE SURVEY OF THE COAST. |
| 1807 | Papers on various subjects connected with the survey of the coast of the United States.—F. R. Hassler.<br>Communicated March 3, 1820. Transactions American Philosophical Society. New Series, Vol. II, pp. 232-418.—[This article gives the plan of organization and operation of the Coast Survey; a description of instruments and apparatus employed, and also the methods of using them.] |
| 1817 | An account of pyrometric experiments made at Newark, N. J.—F. R Hassler.<br>Transactions American Philosophical Society. New Series, Vol. I, pp. 210-227. |
| 1832 | Report on the comparison of measures of length.—F. R. Hassler.<br>Doc. No. 299, pp. 4-9; 20-29; 39-79.—[Coast Survey and weight and measure documents, 1832-1843, volume in Coast Survey Library.] |
|  | PUBLICATIONS BY THE COAST AND GEODETIC SURVEY NOT EMBODIED IN THE ANNUAL REPORTS. |
| 1862 | Coast pilot of California, Oregon, and Washington Territory.—[Second edition.]—George Davidson. |
| 1866 | Standard places of fundamental stars.—B. A. Gould. |
| 1869 | Coast pilot of California, Oregon, and Washington Territory.—[Third edition.]—George Davidson. |
| 1869 | Coast pilot of Alaska. First part from southern boundary to Cook's Inlet.—George Davidson. |
| 1873 | On the air contained in sea water.—Oscar Jacobsen. |
| 1873 | Report on the Nicaragua route for an interoceanic ship-canal, with a review of other proposed routes.—Maximilian von Sonnenstern.<br>Translated for the United States Coast Survey. |
| 1874 | Field catalogue of 983 stars, for time observations; mean places for 1870.—George Davidson. |
| 1874 | Star factors A, B, and C, for reducing transit observations.—George Davidson. |
| 1874 | Tidal researches.—William Ferrel. |
| 1878 | General instructions in regard to inshore hydrography.—C. P. Patterson. |
| 1879 | Secular change of magnetic declination in the United States and at some foreign stations.—[Third edition.]—C. A. Schott. |
| 1879 | Pacific coast pilot, coasts and islands of Alaska. Appendix I. Meteorology and bibliography.—W. H. Dall. |
| 1879 | *Atlantic coast pilot, Division A. Eastport to Boston.—J. S. Bradford. |
| 1880 | *Atlantic coast pilot, Division B. Boston to New York.—J. S. Bradford. |
| 1880 | Deep-sea sounding and dredging.—C. D. Sigsbee. |
| 1880 | On steady motion in an incompressible viscous fluid.—Thomas Craig. |
| 1880 | Catalogue of charts. |
| 1882 | *Atlantic coast pilot, Division C. New York to Chesapeake Bay.—J. S. Bradford. |
| 1882 | *Pacific coast pilot, Alaska.—Dixon entrance to Cape Spencer, with the inland passage.—W. H. Dall. |
| 1882 | Deep-sea sounding and dredging.—C. D. Sigsbee.<br>Supplement to volume of same title by C. D. Sigsbee. |
|  | *Atlantic local coast pilot.—J. S. Bradford. |
| 1879 | Subdivision 1, Passamaquoddy Bay to Schoodic. |
| 1879 | Subdivision 2, Frenchman's Bay to Isle au Haut. |
| 1879 | Subdivision 3, Penobscot Bay and tributaries. |
| 1879 | Subdivision 4, White Head Island to Cape Small Point. |
| 1879 | Subdivision 5, Cape Small Point to Cape Ann. |

## ADDENDA—Continued.

| Year. | Subject and author. |
|---|---|
| | ATLANTIC LOCAL COAST PILOT.—J. S. Bradford—Continued. |
| 1879 | Subdivision 6, Cape Ann to Cohasset. |
| 1878 | Subdivision 7, Boston to Monomoy. |
| 1878 | Subdivision 8, Nantucket and Vineyard Sounds. |
| 1878 | Subdivision 9, Buzzard and Narragansett Bays. |
| 1878 | Subdivision 10, Block Island and Fisher's Island Sounds, and Gardiner's and Peconic Bays. |
| 1878 | Subdivision 11, Long Island Sound and East River. |
| 1878 | Subdivision 12, Harbors in Long Island Sound. |
| 1878 | Subdivision 13, South coast of Long Island, New York Bay and Hudson River. |
| 1882 | Subdivision 14, New York to Delaware Bay. |
| 1882 | Subdivision 15, Delaware Bay and River. |
| 1882 | Subdivision 16, Delaware Bay to Chesapeake Bay. |
| 1882 | Subdivision 17, Chesapeake Bay. |
| 1882 | Subdivision 18, Tributaries to Chesapeake Bay. |
| | A volume of TIDE TABLES of the Atlantic coast, and a volume of TIDE TABLES of the Pacific coast have been published annually since 1867. |
| | NOTICES TO MARINERS are published as occasion may require. From January 14, 1875, they have been numbered in regular order beginning with No. 1. The last one issued is No. 33, dated November 10, 1881. |
| | Books marked with an asterisk (*) are not published for gratuitous distribution, but may be procured at a moderate price. |

# APPENDIX No. 7.

## TYPE FORMS OF TOPOGRAPHY, COLUMBIA RIVER.

WASHINGTON, D. C., *July* 1, 1881.

SIR: In obedience to your instructions for the prosecution of field work in the basin of the Columbia River for the Topographical Manual, I commenced the survey of the Dalles on the 20th of August last, and completed the same September 23. (See Illustration No. 33.) At this reach the river has worn through and carried away the successive layers of basalt for a depth of about 1,000 feet below the present summits, and, as the crests of the escarpments are still visible nearly to the summits, a fine opportunity is presented for the study of the type forms.

The whole volume of the river here runs, for about one and a half miles, through a narrow gorge worn in the basalt, averaging about one hundred meters in width and but sixty meters wide at its narrowest part. During the summer freshet it is much increased in volume, overflows its inclosing walls, follows and overflows some inferior parallel gorges, and is thus greatly increased in width.

The water rushes and foams through the main gorge with great velocity, having a fall, at the time of our survey, of about twenty feet to the mile.

The strata exposed average about seventy feet in thickness, and incline towards the ocean about one hundred and forty feet in a mile. They were all found to be distinct layers of basalt, except at a point on the southeast side of the river and seven hundred feet above the present river level, where a deposit of lime is found; an interesting geological fact, historically.

While the survey was in progress a favorable opportunity was taken to make a trip of observation up the river as far as Wallula, which furnished many objects of topographical interest.

The basin of the Columbia consists of many layers of basalt of such wide area and remarkable uniformity of thickness as to have required the emission of a mass of fused rock such as could only have come through great fissures.

As the forms of hills and mountains composed of eruptive rocks are mainly due—

"1. To the presence or absence, paucity or profusion of structural planes;

"2. To the physical character of the rocks;

"3. To their mineral constitution;

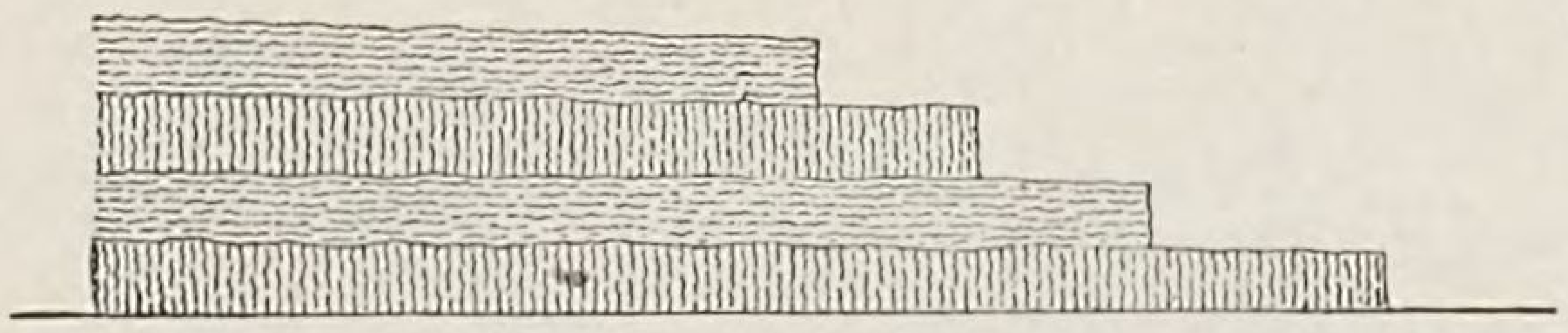
"4. To their chemical composition;"

all of which give direction to the forces of disintegration and erosion, so several distinct types, in accordance therewith, are plainly visible, which comprise the great mass of forms constituting the topography of the basin.

The rock, believed to be 3,000 feet thick, remains in most cases undisturbed in position, with a gentle inclination towards the ocean.

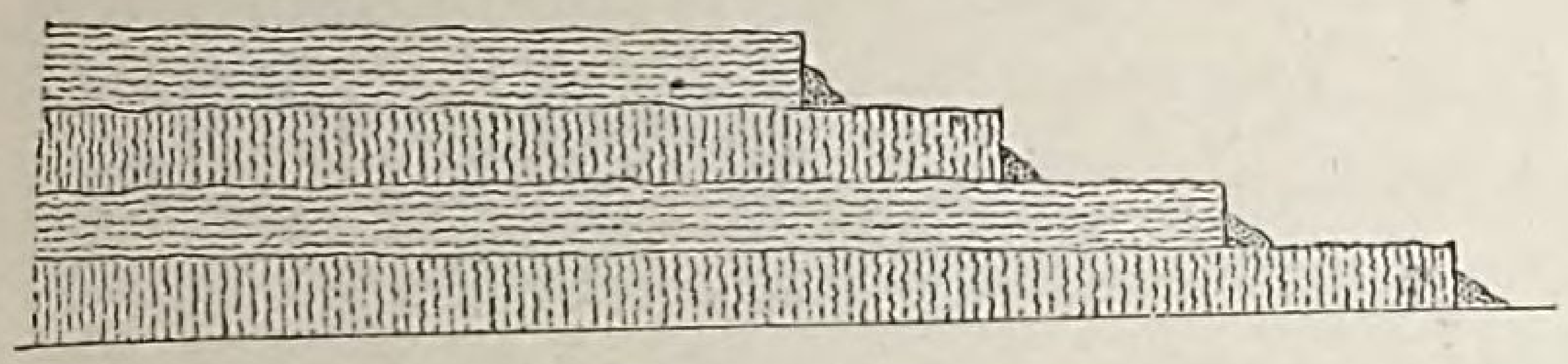
The simplest form presented is the nearly level plain of the undisturbed stratum.

The next is that where, in several successive layers, the whole of the *debris* of each escarpment has been carried away, and a succession of complete sharp escarpments and flat benches is left, forming a profile of the following character:

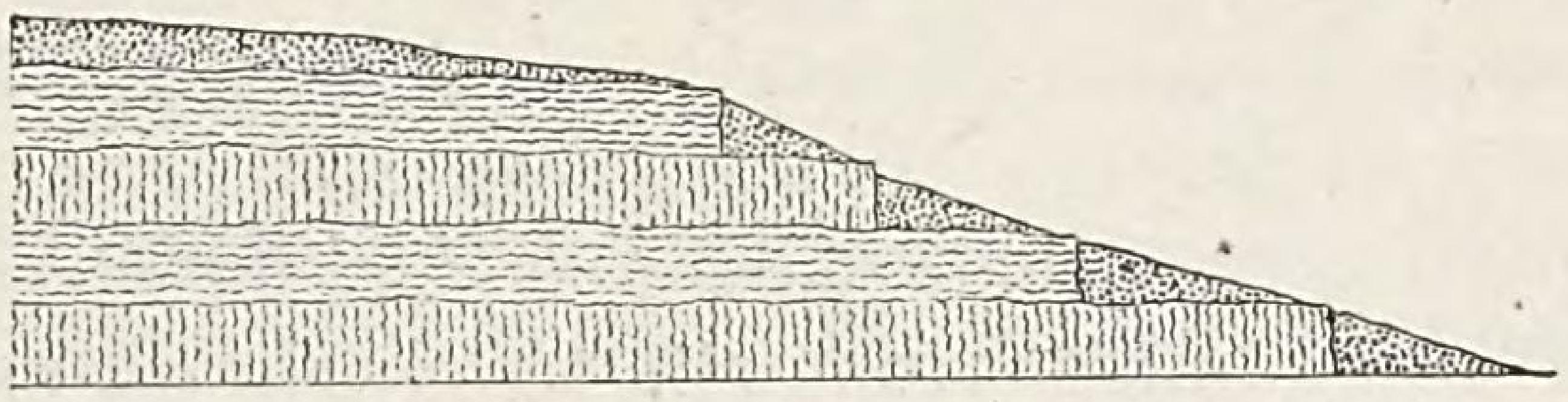


These are usually found near the river level, where the lower escarpments are within reach of the annual floods, and are subject to the maximum atmospheric aqueous action.

Immediately above these, where the forces of disintegration are in excess of those of removal, the escarpments are found with a decided talus of *débris*, rounding off the re-entering angles and forming a profile of the following character:

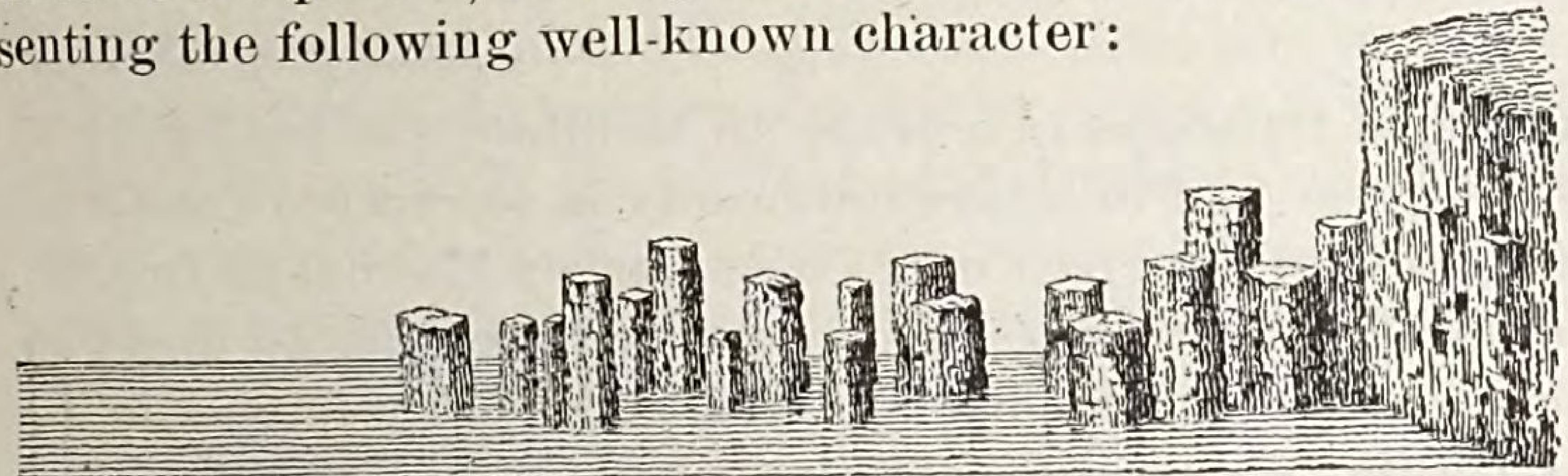


As the ascent is made towards the summits, the re-entering angles are gradually more and more filled in with *débris*, so that the crests only of the escarpments are visible, presenting the following profile:

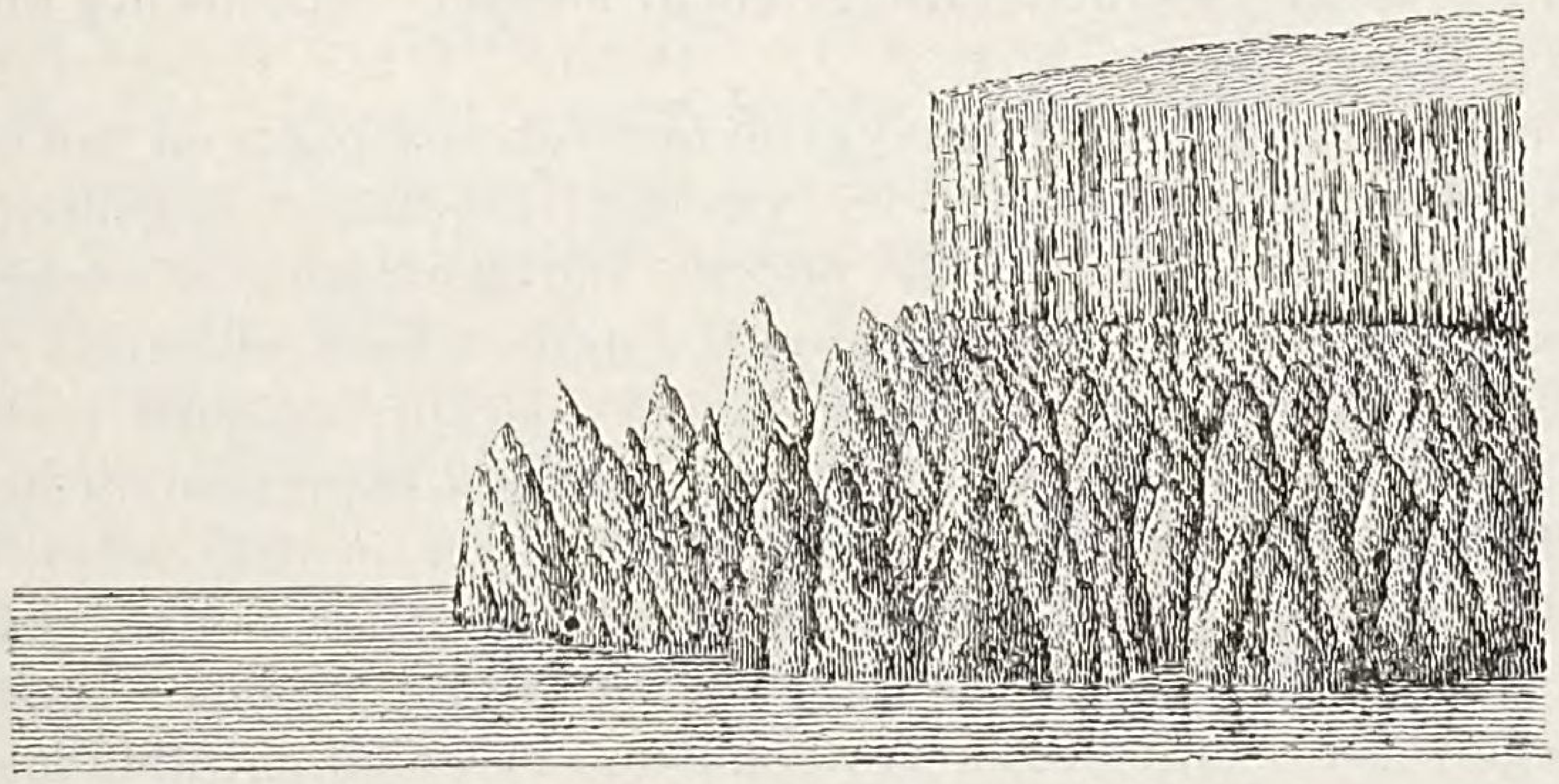


Still farther towards and at the summits the crests of the escarpments disappear altogether, and the forms become those assumed by loose material over successive rigid planes, under the ordinary action of aqueous and atmospheric influences.

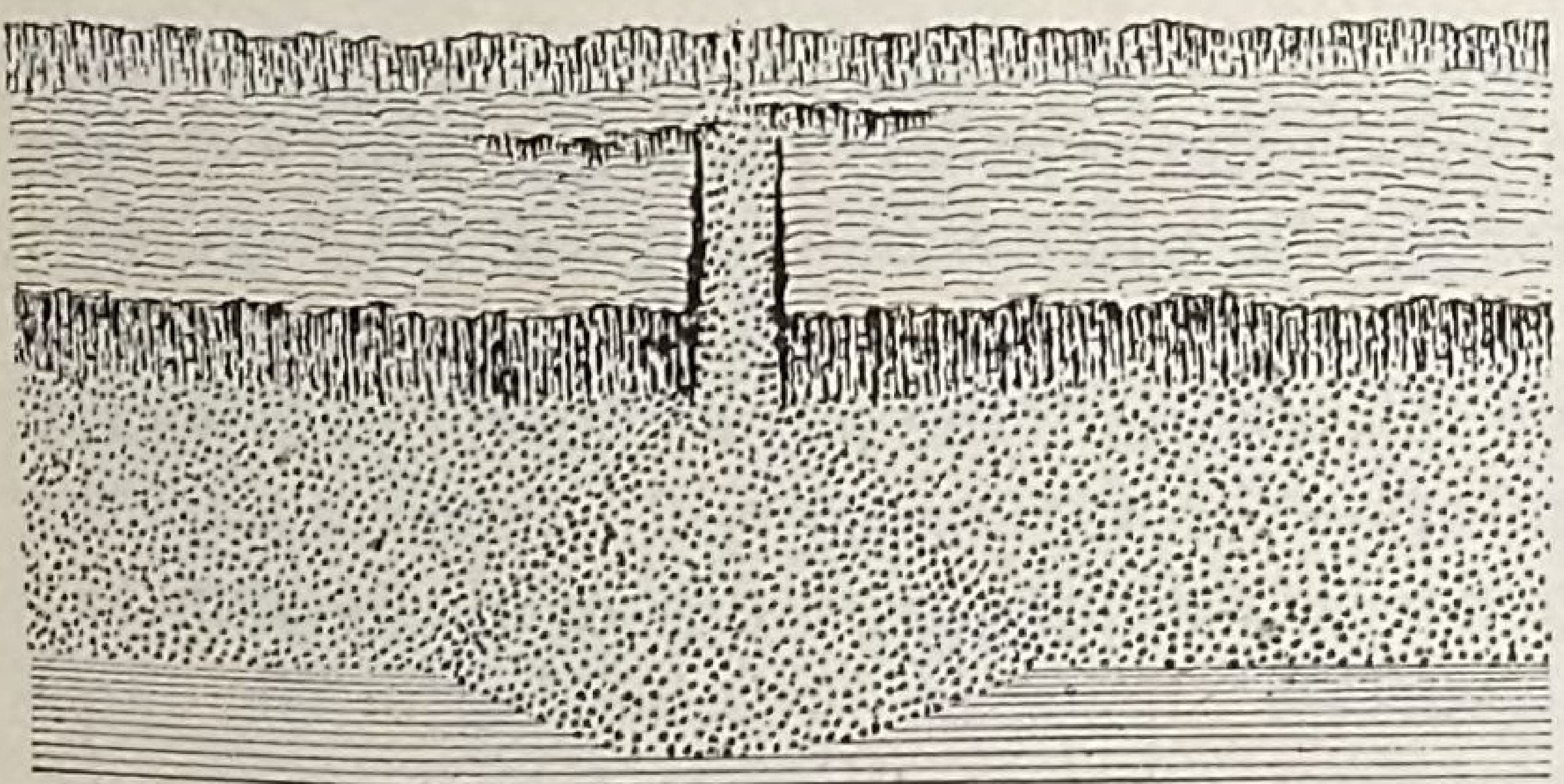
Where a columnar stratum has its base below the level of the river, the erosion and abrasion fracture the prisms, leaving some standing alone, or scattered in groups at different heights, presenting the following well-known character:



In a stratum of homogeneous character, not broken into regular forms by concretionary action in cooling, erosion produces irregular conical forms like pinnacles, as shown below. In some cases a stratum of this character lies immediately under one of marked columnar structure.

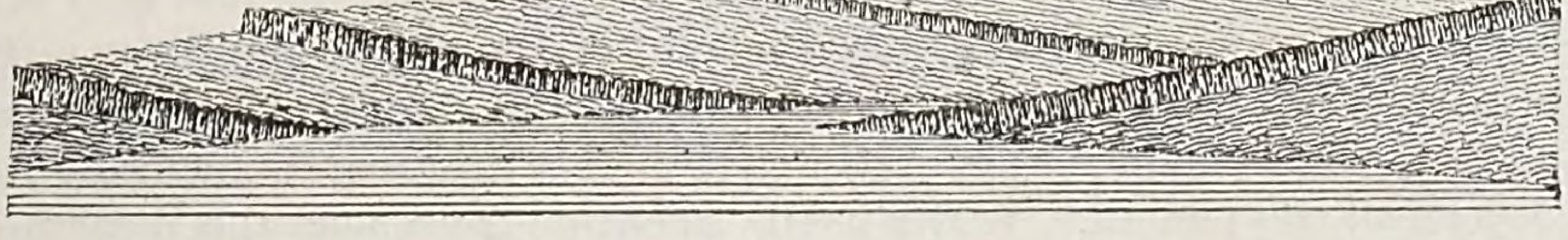


A form frequently seen is where a deep indentation has been worn into a basaltic escarpment (columnar) extending to the base of the next escarpment above. The loose *débris* from the upper escarpment finds its way through the fracture in the lower one, and forms with the *débris* of the fracture upon the general talus a rounded overlying talus projecting into the river, thus:



At a reach above the cascades the inclination of the escarpments towards the river on both sides suggests a possible removal of the lower strata while the upper ones were in a viscous state, so that they bent by their own weight.

It is possible, however, that the undermining may have been comparatively recent, and the mass falling so large that the fractures only appear under the water, and too far back from the river to be observed therefrom. The latter is the more probable, inasmuch as at another point, as I was informed, dead fir trees are standing at a considerable depth in the water. As fir trees do not live in water, they must have grown at a higher level, unless the level of the river should have risen by obstruction in its course below.



Most other forms not included in these types will be found to be fragmentary and due to local causes, but can be traced back without difficulty to the successive basaltic overflows.

Respectfully yours,

E. HERGESHEIMER, *Assistant.*

Mr. C. P. PATTERSON,
*Superintendent United States Coast and Geodetic Survey.*

# APPENDIX No. 8.

## TERRESTRIAL MAGNETISM.

### DIRECTIONS FOR MAGNETIC OBSERVATIONS WITH PORTABLE INSTRUMENTS.

By CHARLES A. SCHOTT, Assistant Coast and Geodetic Survey.

[Third and enlarged edition,* with 4 plates.]

JANUARY, 1882.

1. *Introductory remarks.*—This paper had its origin in a desire to facilitate the field-work of terrestrial magnetism undertaken by the survey and to secure uniformity in the records and computations, and as such was originally intended to form part of a Coast Survey Manual of Instructions. With regard to the first-named object the instructions are given in sufficient detail to enable the observer to produce as accurate results as his instruments will admit of; with reference to the second object forms are given both for recording observations and for computation. The principles and practical methods are given in succinct statements and are illustrated by examples drawn from observations.

The measure of the magnetic force at any place on the earth's surface comprises the determination of its direction and its intensity; the former is generally given with reference to the planes of the meridian and of the horizon and the latter is expressed either in relative measure or in absolute measure, depending on the unit of force selected. There are two classes of observations made on the survey, each employing specially adapted instruments. They are of an essentially different character, the first giving results expressed in absolute measure, the second yielding differential results only. With these latter, or differential observations made at fixed magnetic observatories and needing photography for continuous registry, this paper is not concerned; but it will contain a full account of the usual methods, instruments, records and computations employed in magnetic surveys on shore in which portable instruments are used.

Wherever we may expose a magnet, free to move, we will find the space it occupies traversed by lines of force, due to the magnetism of the earth, and the magnet will place itself with its axis parallel to these lines of force. The direction of the magnetic force at any place and time will then be known by the direction a freely suspended magnetic needle will assume and will be defined by the azimuth of the vertical plane passing through the magnetic axis of the needle and by the angle in that plane this axis makes with the plane of the horizon; the former angle is generally known as the magnetic declination (and by the navigator as the variation) and is measured in the plane of the horizon; the latter angle is generally known as the magnetic dip or inclination and is measured in a vertical plane. The intensity of the earth's magnetic force, acting in the direction of a freely suspended needle, is known as the total force at that place and time; it may be made the subject of measure, but more frequently the measure of the horizontal component of the magnetic force is preferred. The force with which a magnetic needle will resist any attempt to deflect it from its position of equilibrium depends upon the intensity of the earth's magnetic attraction as well as upon the magnetic moment of the magnet, and the latter has therefore to be separated from the former before we can express the magnetic force in absolute measure. In general the horizontal component can be determined with greater accuracy than either the total force or its vertical component. While in the scientific treatment the direction and intensity of the magnetic force are inseparably connected, it is different in the practical application of magnetism for the uses of the surveyor and navigator, to whom the directive property of the magnetic needle is of far greater interest and value than the magnitude of the force. Thus, the surveyor is frequently called upon to retrace old magnetic courses by which land boundaries had been originally defined and which in the course of time had fallen into litigation; to do this effectively he will not only require to know the magnetic declination at present and at the place in question, but he must also possess an accurate knowledge of the secular change of the declination[*] in order to make proper allowance for its effect during the interval between the two epochs of the survey. In the daily practice of navigation the solution of the problem of converting magnetic into true bearing is continually required; this involves on the part of the navigator a knowledge of the magnetic declination for the place and time, while the intensity enters entirely as a matter of secondary importance in the treatment of the deviation of his compass due to the disturbance of the ship's magnetism and, may be, that of the cargo. The methods for measuring the declination, dip and intensity on board ship will not be included in this paper and must be sought for in treatises on navigation; they are, however, not essentially different from certain methods employed on shore and can readily be understood. At sea the azimuth compass takes the place of the declinometer for the determination of the horizontal direction and the Fox circle is substituted for the dip and intensity circle in determining the inclination and relative total force which, by the aid of a land station, can finally be expressed in absolute measure.

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* This paper was first published in the Coast Survey report for 1872, Appendix No. 14, and illustrated by 2 plates; the second edition appeared in the report for 1875, Appendix No. 16, and was illustrated with 4 plates.

2. *Selection of stations.*—The subject can most convenintly be presented under the heads:

1. Determination of the magnetic declination.
2. Determination of the magnetic dip.
3. Measure of the magnetic force.

Before entering upon it some remarks are desirable respecting a proper selection of stations at which to make observations. The principal condition that ought to be satisfied at any station is that of freedom from possible disturbing influence, either in the soil itself or from near presence of iron; places near foundries, steamboats and locomotives, and objects of iron or steel, as guns, pipes, railings, rafters, rails, posts, rods, wires, &c., can readily be avoided, though no general rule can be given of what might be regarded a safe distance, which may vary from 50 to 500 meters or more. The geological formation[†] of the locality cannot be made a guide whether or not local deflections exist, since such influence may be quite deeply seated; but it is recommended in all cases to make special instrumental test for local disturbance by carrying an azimuth compass successively over a series of points along two straight lines crossing each other at right angles at the station and observing at each point the bearing of a distant object several kilometers or miles off, in order that there may be no parallax (or else allowing for it) and comparing the results; if these accord within the inevitable observing error the place may be free from local deflection. A more simple but less accurate method, yet well adapted when vertical polarity is suspected, is that of carrying a dip circle over the lines and testing the dip at the several points; of course no reversal of either circle or needle is made. The observer must divest himself of any objects of iron or steel, as knives or keys, while manipulating his instruments.

### I.—DETERMINATION OF THE MAGNETIC DECLINATION.

3. *Definition.*—The magnetic declination of any place, being the angle contained between the astronomic and magnetic meridians, requires for its measure two distinct operations, namely: The determination of the astronomic meridian, which is generally done by means of a theodolite; and the determination of the magnetic meridian by means of the declinometer or unifilar magnetometer. The former of these planes is fixed, the latter variable, and the observations may have for their object the determination of the declination at a given epoch or hour of the day, or of its average value for any one day, month, or year.

4. *Finding the true meridian.*—Respecting the determination of the astronomic meridian from observations of the azimuth of the sun or of a star, full information will be found in the third edi-

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[*] See paper on Secular Change of Magnetic Declination in the United States and at some Foreign Stations, fourth edition, in Coast and Geodetic Survey Report for 1879, Appendix No. 9. Washington, 1881.

[†] In his report of 1878–'79, Appendix VII, of the Geological Survey of Canada (Montreal, 1880), Mr. Selwyn, director of the survey, remarks: "Among other causes influencing the magnetic declination in this region (vicinity of Lake Winnipeg) besides that of change in the geological formation on a large scale, I have noticed beds of magnetic iron, deposits of iron sand, dikes of diorite, great magnetic bowlders, sudden change in the general level, proximity of a cliff or bank or even of a thick grove, or when very close, a single large tree." In the last-mentioned cases, if true, evidently very peculiar conditions of action of electric currents had to be supposed.

tion of a paper entitled, "Determination of Time, Longitude, Latitude, and Azimuth," in Coast and Geodetic Survey Report for 1880, Appendix No. 14. The example of observations and reduction given in Article 11 of the part treating of the azimuth is taken from a record made in connection with magnetic work. It may be stated that for magnetic purposes a very moderate degree of accuracy suffices in the determination of the true meridian and a correct knowledge of it within 1′ will in general fully suffice. It is difficult, even in our middle latitudes, to determine the magnetic meridian within the limit of 1′ on account of the continuous fluctuations, hence any greater accuracy than this in the astronomic meridian would be useless. To define the true meridian beyond its mere circle-reading on the theodolite, the angle between it and a mark (any conspicuous object) is measured and the true azimuth of that mark becomes known and is available at any time. In order to obtain the magnetic declination we need only to find the magnetic azimuth of the mark and the difference between the true and magnetic bearings is the declination. To distinguish between west and east declination, a + sign signifies that the north (seeking) end of the magnet (or needle) or the magnetic north direction lies to the west of the true north meridian, in short, west declination; a — sign signifies the contrary, or east declination. These signs apply to the southern as well as to the northern hemisphere. Before describing the use of the magnetic instruments proper, the following article will be devoted to the adjustment and use of the astronomical theodolite in connection with the determination of the true meridional line.

5. *Adjustment of the theodolite and alt-azimuth instrument.*—The various operations for placing the parts of a theodolite in proper condition for observing, in order to eliminate, as far as possible, sources of error arising from instrumental defects, may be briefly stated as follows:

*To adjust the levels.*—After properly setting up the stand, clamping it and mounting the instrument, adjust the most sensitive of the levels attached to it by bringing two of the foot-screws of the theodolite in line with the direction of the level, and after leveling, turn the azimuth circle 180°, correct any defect, one-half by means of the foot-screws (always working them in opposite directions), the other half by means of the adjusting-screws of the level; turn the circle back to first position and repeat the correction as before as often as may be necessary. If during this operation we turn the circle once or twice at right angles to the former position and make the bubble play in the middle by turning the third foot-screw of the theodolite, there may be no need of using the *graduation* to effect the adjustment of the level, the turning of 180° by estimation being sufficient to effect the purpose. If there is a second level attached to the circle at right angles to the former, it may be adjusted like the first, or more expeditiously, by placing it in the same direction as the first (when in adjustment) and correcting any defect by its correcting screw. Circular levels must be adjusted upon the same principles; they are, however, generally of inferior accuracy.

*To place the axis of the azimuth-circle vertical.*—By means of the adjusted level we place the vertical axis in position by leveling the instrument with the two foot-screws parallel with the direction of the level and then turning the circle 90° and bringing the bubble again to the middle by turning the third foot-screw. The verticality of the axis is tested by the steadiness of the bubble in the middle of the tube when the instrument is slowly revolved in azimuth.

*To adjust the threads of the telescope.*—Place the threads in the focus of the eye-piece where their best definition is obtained and test the position by pointing to a distant well-defined object to which the focus of the object-glass is adjusted for distinct vision; and if by moving the eye sidewise the object appears to move off the thread or pointing in the same direction as the eye, the diaphragm must be slightly pushed in, and pulled out in the contrary case. If there are two threads intersecting in the middle of the field at right angles, the vertical thread may be set vertical by sighting a plumb-line suspended at a proper distance, or the vertical edge of a house may be used instead. The whole diaphragm (after loosening its four screws) is to be turned around the optical axis to effect the coincidence. The preceding adjustment must not be disturbed. The horizontal thread may also be tested by pointing to an object and then turning the azimuth-circle, previously set horizontal, when the object should remain bisected; it may also be effected by pointing on the sea-horizon.

*To adjust the line of collimation of the telescope.*—If the horizontal axis of the telescope admits of being reversed in its supports, a distant object is pointed to; and if, after reversal of the axis in its V's, the pointing remain perfect, the line of collimation is at right angles to the axis; if not, half of the difference is to be corrected by the azimuth screw and half by the two adjusting screws of the diaphragm (its former adjustments remaining undisturbed). If the axis does not admit of reversal in the V's, it must be reversed by reversal of the circle, using the graduation; and if the second reading, after reversal, should differ from it a little more or less than 180°, the difference must be corrected as before and the process is to be repeated until the readings, direct and reversed, differ by 180° exactly. For greater accuracy, we may use a collimator instead of the distant object. In some instruments the telescopes are mounted on one side instead of in the middle of the azimuth-circle; their collimation may be corrected by two distant marks separated exactly by twice the eccentricity of the axis of the telescope from the vertical axis of the theodolite. The process of adjustment is then the same as described, only changing the mark with a change of the telescope from one side to the other. For oblique intersections of the threads the point of intersection must be brought into the optical axis of the telescope, the adjustment for collimation being the same as described. In this case a collimator with a vertical thread is used to advantage.

*To place the horizontal axis of the telescope in position.*—This axis must be at right angles to that of the azimuth-circle, and if in position or horizontal the line of collimation, when revolving the telescope, must pass through the zenith of the observer. It is effected by placing an adjusted level on the axis and correcting the whole error with the adjusting screw of the pivot. If the level is fixed or uncorrected, it must be adjusted at the same time with the axis by leveling and then turning the azimuth-circle 180°, and correcting one-half of the defect by the pivot-screw and the other half by the level-screw. This process also requires repetition for its perfection.

The instrument is now ready for the measurement of horizontal angles, either by "directions" or by "angles," with or without repetitions, according to the construction of the instrument or the requirements of the case. In either method one-half of the measures must of course be made with "circle direct," the other half with "circle reversed" by 180°, which process corrects the angles for any *remaining defect*, after adjustment, in the verticality of the axis, in the height of the V's, in the form of the pivots, and in the collimation. If the telescope is placed eccentrically, this reversal will at the same time refer the resulting measures to the axis of the circle, or what should be the same, to the vertical of the station.

In repeating angles it suffices to record the readings of the circle at the commencement and at the end of the operation, the telescope being reversed after half the number of repetitions are secured. During the reversal of the telescope the circles remain firmly clamped until after the new pointing is made. With non-repeaters, or when used as such, the records for telescope "D" and for telescope "R" are kept separate.

The eccentricity of a circle is corrected by taking the mean of the readings of two opposite verniers or microscopes, or the mean of the readings of any number of verniers or microscopes, provided they are so placed as to divide the whole circumference into equal parts.

*To adjust the level required for vertical measures.*—The measures of vertical angles depend, among other things, on the accuracy of the adjustment of the level. It is effected by leveling and reversing the azimuth circle 180°, using one of the level screws for correction, provided the former adjustment of the vertical axis has not been disturbed. This level may either be attached to the azimuth-circle or to the arms carrying the verniers or microscopes of the altitude-circle; in the former position it is of course placed parallel to or in the plane of the altitude-circle.

The instrument is now in the proper condition for the measure of vertical angles. Generally *double* zenith distances are measured, by means of which the reading of the zenith (or nadir) point on the circle becomes known and consequently also the reading of the horizon. If there is any index-error, it may either be corrected (many instruments admit of such a correction) or it may be allowed for as a constant when single altitudes are measured. This index-error is of no consequence if double zenith-distances are taken (involving positions, circle right and circle left).

Owing to the great diversity in the construction of theodolites, depending upon the particular use and the degree of perfection required of them, rules cannot be given to apply alike to all constructions; but the preceding notes on adjustment will suffice in all ordinary cases of the use of the portable instrument. To test the graduation, its eccentricity, systematic and irregular errors; to adjust the reading microscopes (for run and focus); to test the coincidence of the two horizontal axes, also of the two vertical axes, *in repeating instruments;* to examine the perpendicularity of the planes of the circles (graduation) to their respective axes; to measure the flexure of the telescope and other circumstances, will require the attention of the observer when engaged in the more refined geodetic or astronomical use of the alt-azimuth.

The principle of repetition applies most advantageously when the optical power of the telescope exceeds relatively the accuracy of the graduation; in other words, when the pointing-error is less than the graduation-error. If the optical power is inferior, or not commensurate with the perfection of the graduation, we may still use the method, the number of repetitions being arranged so as to spread the readings over the graduation. Although the principle of repetition is an elegant one, in practice it has been found frequently to introduce a new source of error, namely, a constant or slowly variable error depending on imperfection of the clamping, friction and general instability of the instrument. Unless the clamps are perfect, repeating will introduce a constant error, which cannot be eliminated from the result by the forward and backward movement of one circle upon the other and the observer should carefully test whether or not his pointing will be preserved when repeatedly clamping and unclamping; this especially applies to the clamps upon which the movement of the inner circle depends (for repeaters). The clamps and fine motion screws should never be at the circumference of the circle of graduation, but near the axis, unless for inferior instruments. Before adjusting the instrument its clamping apparatus should be examined as well as the proper amount of friction of the moving parts and the balancing of weights. Instruments with *light* spokes to their azimuth-circles (though they may otherwise be high or thick enough), and having a heavy superstructure (vertical circle and counterpoise), frequently show so much flexure or spring as to affect injuriously all horizontal measures, while *full* thin plates are not liable to this defect.

Azimuths in connection with the magnetic declination, where an accuracy of a fraction of a minute suffices, may be obtained with a small alt-azimuth instrument say of four or five inches diameter (about 10 to 13$^{cm}$). Supposing the latitude given, but the time only approximately known, the sun's zenith distance and azimuth may be observed as follows: reading of mark, three readings of the sun's upper and first limb, with noting of the chronometer time of contacts; instrument reversed, three readings and timing of the sun's lower and second limb, reading of mark.

Let $h$=altitude, corrected for refraction, parallax (semi-diameter and dip, if necessary), and $p$=the sun's or star's polar distance, then

$$\tan^2 \tfrac{1}{2}A = \frac{\sin(s-\varphi)\sin(s-h)}{\cos s \cos(s-p)}$$

in which expression $s = \frac{1}{2}(\varphi + h + p)$. If the time should also be desired, it may be computed by

$$\tan^2 \tfrac{1}{2}t = \frac{\cos s \sin(s-h)}{\sin(s-\varphi)\cos(s-p)} \quad \text{or by} \quad \tan \tfrac{1}{2}t = \cot \tfrac{1}{2}A \frac{\sin(s-h)}{\cos(s-p)}.$$

If the sun's limb is observed, the correction to the azimuth for reduction to center is $\pm \frac{r}{\sin \zeta}$, where $r$ = sun's radius; whether + or − sign is to be used will readily be known in each particular case. $t$ is the hour-angle.

If the local time is known, we may observe Polaris for azimuth and latitude, computing the former by the fundamental formula, in which the azimuth A is counted from the north

$$\tan A = \frac{\sin t}{\cos \varphi \tan \delta - \sin \varphi \cos t}$$

and the latter by

$$\varphi = h - p \cos t + \tfrac{1}{2} \sin 1'' (p \sin t)^2 \tan h.$$

For greater accuracy, we may observe the star direct and reflected in mercury.

The following two examples will serve to illustrate the methods:

### *Example of record and reduction.*

STATION, WASHINGTON, D. C., IN PARK EAST OF THE CAPITOL.

Sun near prime vertical. August 15, about 8$^h$ a. m., 1856. Observer, C. A. S. Instrument, five-inch magnetic theodolite. Sidereal chronometer.

| Chronometer time. | Horizontal circle. | | Vertical circle. | | Temperature. |
|---|---|---|---|---|---|
| | A. | B. | A. | B. | |
| SET I. | ⊙'s upper and first limb. Telescope D. | | | | 73° Fahr. |
| *h. m. s.* | ° ′ ″ | ° ′ ″ | ° ′ ″ | ° ′ ″ | |
| 5 02 53.0 | 25 24 30 | 205 24 30 | 61 56 00 | 61 56 00 | (Barom. 30 in., assumed.) |
| 05 34.0 | 25 50 45 | 205 51 30 | 61 24 30 | 61 25 00 | |
| 06 55.5 | 26 04 30 | 206 05 .15 | 61 08 45 | 61 09 30 | |
| | ⊙'s lower and second limb. Telescope R. | | | | |
| 5 09 12.0 | 205 54 15 | 25 54 00 | 61 19 30 | 61 18 30 | |
| 10 32.0 | 206 07 15 | 26 06 45 | 61 04 00 | 61 03 00 | |
| 11 42.0 | 206 18 30 | 26 18 15 | 60 50 00 | 60 49 45 | |
| SET II. | ⊙'s lower and second limb. Telescope R. | | | | |
| 5 13 22.0 | 206 35 30 | 26 35 30 | 60 30 45 | 60 30 15 | |
| 14 32.0 | 206 47 30 | 26 47 30 | 60 17 30 | 60 17 00 | |
| 15 36.5 | 206 58 30 | 26 58 00 | 60 05 15 | 60 04 30 | |
| | ⊙'s upper and first limb. Telescope D. | | | | |
| 5 17 07.0 | 27 47 30 | 207 48 15 | 59 11 45 | 59 12 00 | |
| 18 16.5 | 28 00 00 | 208 00 30 | 58 57 45 | 58 58 00 | |
| 19 19.0 | 28 10 15 | 208 10 30 | 58 45 30 | 58 45 15 | |
| SET III. | ⊙'s upper and first limb. Telescope D. | | | | |
| 5 20 44.0 | 28 25 00 | 208 25 00 | 58 29 00 | 58 29 30 | |
| 22 01.5 | 28 37 45 | 208 38 15 | 58 14 45 | 58 14 30 | |
| 25 26.5 | 29 13 30 | 209 14 00 | 57 36 00 | 57 35 45 | |
| | ⊙'s lower and second limb. Telescope R. | | | | |
| 5 27 32.5 | 209 01 30 | 29 00 30 | 57 48 00 | 57 47 30 | |
| 28 39.5 | 209 12 45 | 29 12 15 | 57 34 30 | 57 34 15 | |
| 30 01.0 | 209 27 00 | 29 26 30 | 57 19 15 | 57 18 30 | 78° Fahr. |

$\phi = 38° 53' 18''$. $\lambda = 5^h\ 08^m\ 01^s.8$ west of Greenwich.

| | Mean chronometer time. | Mean reading horizontal circle. | Mean reading vertical circle. | Correction for parallax in altitude and refraction. | Corrected $\zeta$. |
|---|---|---|---|---|---|
| | *h. m. s.* | ° ′ ″ | ° ′ ″ | ′ ″ | ° ′ ″ |
| Set I.... | 5 07 48.1 | 25 56 40 | 61 17 02 | + 1 34 | 61 18 36 |
| Set II... | 5 16 22.2 | 27 23 17 | 59 38 00 | + 1 27 | 59 39 27 |
| Set III.. | 5 25 44.1 | 28 59 30 | 57 50 07 | + 1 21 | 57 51 28 |

| | Set I. | Set II. | Set III. |
|---|---|---|---|
| | ° ′ ″ | ° ′ ″ | ° ′ ″ |
| $\phi$ | 38 53 18 | 38 53 18 | 38 53 18 |
| $h$ | 28 41 24 | 30 20 33 | 32 08 32 |
| $p$ | 76 04 27 | 76 04 37 | 76 04 44 |
| A (from north) | 95 06 06 | 96 32 34 | 98 08 54 |
| Circle reads | 25 56 40 | 27 23 17 | 28 59 30 |
| South meridian reads | 110 50 34 | 110 50 43 | 110 50 36 |

Hence the north meridian reads 290° 50′ 38″.

We shall also find the chronometer slow of sidereal time 16$^m$ 05$^s$.1, the results by the sets agreeing within a fraction of a second.

*Example* 2.—Station, Magnetic Observatory, Capitol Hill, Washington, D. C. Polaris near lower culmination. May 23, 1873 (observations made during evening twilight). Observer, C. A. S. Instrument, 2¾-inch (7$^{cm}$) Casella theodolite No. 3524; sidereal chronometer Kessels 1287. Noon-ball at United States Naval Observatory dropped on May 17 at 4$^h$ 55$^m$ 32$^s$.5 and on May 24 at 5$^h$ 23$^m$ 15$^s$.5 chronometer time. The latitude of the magnetic station is 38° 53′.1 and the longitude 11$^s$.6 east of the United States Naval Observatory.

| Object. | Circle. | Chronometer time. | Azimuth circle. | | Vertical circle. | |
|---|---|---|---|---|---|---|
| | | | A. | B. | A. | B. |
| | | *h. m. s.* | ° ′ | ° ′ | ° ′ | ° ′ |
| Mark | R. | | 0 00 | 180 03 | [177 01] | [357 02] |
| Mark | L. | | 180 05 | 0 03 | [3 00] | [182 57] |
| Polaris | L. | Dir. 13 16 46 | 169 58 | 349 55 | 37 36 | 217 39 |
| Polaris | L. | Ref. 24 55 | 169 59 | 349 58 | 322 29 | 142 24 |
| Polaris | R. | Dir. 13 40 20 | 350 08 | 170 06 | 217 30 | 37 29 |
| Polaris | R. | Ref. 45 37 | 350 06 | 170 07 | 142 23 | 322 25 |
| Mark | R. | | 0 02 | 180 04 | | |
| Mark | L. | | 180 05 | 0 04 | | |

Star seen through thin clouds, occasionally interfering with observations. Atmospheric pressure, 29.85 inches; atmospheric temperature, 70° Fahrenheit. The small porcelain cup (4 cm. diameter) containing the mercury was placed on the stand of the theodolite.

Computing for circle left and circle right, separately, we find

| | *h. m. s.* | *h. m. s.* | ° ′ ″ |
|---|---|---|---|
| Chronometer time | 13 20 50 | 13 42 59 | Also $\delta$ = 88 37 44 |
| Chronometer correction | − 1 13 36 | − 1 13 36 | $p$ = 1 22 16 |
| Sidereal time of observation | 12 07 14 | 12 29 23 | |
| $\alpha$ Polaris | 1 11 28 | 1 11 28 | |
| $t$ | 10 55 46 | 11 17 55 | |
| | ° ′ | ° ′ | |
| Also $h$ observed | 37 35.5 | 37 32.8 | |
| Correction for refraction | − 1.2 | − 1.2 | |
| $h$ | 37 34.3 | 37 31.6 | |

With these data we find

A = 0° 28′ 42″ and 0° 18′ 57″
Star reads 169 57 .5 and 170 06 .8
Meridian 170 26 .2 and 170 25 .8 Mean 170° 26′.0
Mark reads 180 03 .2

Mark E. of N. 9 37 .2 ± 0′.4

Also, $\varphi$ = 38° 53′.5 and 38° 52′.5
Hence, latitude 38 53 .0 ± 0′.4

6. *Adjustment of the declinometer and magnetometer.*—That form of construction of the instrument which has the box with its suspended magnet mounted over the center of the graduated or azimuth-circle and which is due to the late Dr. Lamont, of Munich, is generally known on the Survey as a theodolite-magnetometer (see No. 35 of the accompanying plates). It is especially well adapted for work in a fixed observatory, gives superior accuracy to the measure of the horizontal force and will always indicate the magnitude, however large, of any disturbance in the direction of the declination. On the other hand it is not suited, except roughly, for the determination of the astronomical azimuth, for which reason the second form of instruments is preferred in magnetic surveys. This form, which was the earlier one, was given by Gauss and Weber (see No. 34 of plates); the theodolite, or alt-azimuth, is detached from the magnetic part of the instrument; it is known either as a "declinometer," if not provided with means for determining intensity (such as a second or deflecting magnet, deflecting bars, mass ring, &c.) or as a "magnetometer," if it is provided with all necessary appliances for determining declination as well as absolute horizontal magnetic force. In the earlier practice on the Survey the theodolite was mounted on a separate stand and collimated with the magnet at a distance of a few centimetres; later on, however, theodolite and magnet box were mounted closely together on a board resting on a tripod. This greatly facilitated the operation of collimation. More recently a combination instrument was devised (see No. 36 of accompanying plates). It may be described as an alt-azimuth instrument which admits of a removal of the upper structure (the Y's, telescope and vertical circle) and the substitution for it of the box with suspended magnet and attached reading telescope. Here, then, we have two telescopes, but the advantages of each of the two forms of instrument combined in one. The observer may arrange his magnet so that in collimating he may either look south (magnetically) or north and the change from one direction to the other can be made by exchanging the lens and the plane glass of the collimator magnet; but if, as usual, this magnet is also used as intensity magnet or serves for oscillations, it must not be disturbed by any such exchange *after the constants have been once determined.* When using in field-work a declinometer or magnetometer with separate theodolite it will be found preferable for the observer to stand north of his instrument and looking south in collimating, as in this case he may more readily manipulate the theodolite for observations of azimuth without taking off the magnetic box. Should he use a theodolite magnetometer or the combination instrument, he will find it advantageous to collimate looking north, as the sun will then interfere less with vision, and generally he may throw more reflected light through the collimator. There are other forms of magnetic instruments for the determination of the declination and the intensity, but these offer no special difficulty in their use.

The station having been selected, apparently free from local magnetic disturbance, the instrument is mounted with the sides of the box containing the magnet directed nearly north and south magnetic, which may be done most conveniently by means of a small compass needle; then the instrument will be leveled and the theodolite with telescope will be adjusted.

The motion of the magnet is controlled by the observer by means of a small piece of magnetized steel (a small screw-driver, for instance), its magnetism (at its free end) being the same as that of the end of the magnet facing the observer, so as to repel it when brought near. It must neither be too strong, nor be brought too close to the magnet, otherwise the position of the magnetic axis might be disturbed. The suspension-tube should carry at its top a rack and pinion to admit of an easy vertical movement of the magnet. With a piece of cloth at the bottom of the box, the magnet can be let down and allowed to come to rest by friction on the fibers of the cloth; it can then be raised and quickly steadied by the magnetized screw-driver, all without opening the box, which in windy weather must be avoided. The sides of the box, if of glass sliding in grooves, must have pasteboard covers to darken it, and the width of the slit facing the mirror must be specially regulated for the best definition of the scale; the shade placed over the object end of the telescope should nearly touch the box, in order that all stray light may be excluded. The special adjustments to be made are the following:

Suspend the torsion-cylinder, which is of the same weight precisely as the magnet and take out the twist of the suspension-fibers, of which there should not be more than are absolutely needed to support the weight without risk of breaking—say about 4 or 6 for the older heavy magnets and 1 or 2 for the light ones. With the aid of the rack-motion and the friction on the cloth, the whole turns of twist are readily taken out, and then the line of detorsion must be placed in the magnetic meridian, in which position the axis of the torsion-weight must be parallel with the side of the box.* In packing, the suspension should be kept free of twist, so that at any new station only the small changes developed in the twist during the interval need attention. The weight should be removed, the magnet suspended and the telescope pointed nearly to the middle of its scale, or to the axis of the magnet. The axis of the collimator and the line of collimation of the telescope should then be, as nearly as possible, in the same straight line. To render the scale distinct, the telescope must be set to sidereal focus. The azimuth-circle is then read; the reading, when pointing to the mark,† having previously been recorded. The relative position of the theodolite and magnet is, of course, invariable, both being supported by the same stand.

The scale-reading of the magnetic axis of the collimator is determined by readings with scale erect and inverted, as shown in the following example:

*Observations for axis of magnet $A_1$.*

| Magnet. | Scale-reading. | | Mean. | Means of 1 and 3, 2 and 4, &c. | Axis. |
|---|---|---|---|---|---|
| | Left. | Right. | | | |
| E. | 11.0 | 13.0 | 12.00 | | *d.* |
| I. | 7.5 | 5.7 | 6.60 | 12.00 | 9.30 |
| E. | 10.9 | 13.1 | 12.00 | 6.55 | 9.28 |
| I. | 7.4 | 5.6 | 6.50 | 12.05 | 9.28 |
| E. | 11.5 | 12.7 | 12.10 | 6.50 | 9.30 |
| I. | 7.3 | 5.7 | 6.50 | 12.07 | 9.29 |
| E. | 11.3 | 12.8 | 12.05 | | |
| | | | | Mean | 9.29 |

NOTE.—It is recommended to make these observations about the epoch of the day when the magnet is nearly stationary, or between 7 and 8 a. m., from May to September, inclusive; in March, April, and October, about 8 a. m. and in January, February, November, and December, about 9 a. m.; also about 1½ p. m. in any month and in any part of North America.

The angular value of a division of the scale is determined by successive pointings on the principal divisions and noting the corresponding readings of the azimuth-circle, and repeating the operation in the reverse order. With that form of the instrument which has the box of the magnet connected with the azimuth-circle, the combination of the results will correct for change of declination during the measures, but a small correction for torsion may be needed; for the other form of construction the magnet may be fastened in its normal position during the scale measures. The usual value of a scale-division is between 1′ and 3′ and tenths may be estimated. It is only for those instruments which give primarily the amount of deflection, in the intensity-measures, expressed in scale-divisions, that an accurate determination of the scale-value is needed.

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* This process may require repetition until the observer is assured that there is no torsion when the collimator-magnet is suspended.

† The best position of the mark is in or near the horizon.

*Determination of scale-value of magnet* $C_{16}$.

| Scale. | Theodolite-circle, mean of two readings. | | | Value of eighty divisions. 10–90, 20–100, &c. | | |
|---|---|---|---|---|---|---|
| *d.* | ° | ′ | ″ | | | |
| 10 | 159 | 04 | 25 | | | |
| 20 | 158 | 36 | 30 | | | |
| 30 | 158 | 08 | 15 | | | |
| 40 | 157 | 40 | 35 | | | |
| 50 | 157 | 12 | 35 | | | |
| 60 | 156 | 44 | 30 | | | |
| 70 | 156 | 17 | 05 | | | |
| 80 | 155 | 49 | 00 | ° | ′ | ″ |
| 90 | 155 | 21 | 15 | 3 | 43 | 10 |
| 100 | 154 | 52 | 30 | | 44 | 00 |
| 110 | 154 | 24 | 45 | | 43 | 30 |
| 120 | 153 | 57 | 30 | | 43 | 05 |
| 130 | 153 | 28 | 20 | | 44 | 15 |
| 140 | 153 | 00 | 50 | | 43 | 40 |
| 150 | 152 | 33 | 00 | | 44 | 05 |
| 160 | 152 | 04 | 30 | | 44 | 30 |
| | | | Mean | 3 | 43 | 47 |

Hence one division of scale$=2'.797$

NOTE.—If the number of pointings is odd instead of even, as above, the mean reading corresponding to the *middle* division must be found and subtracted from each separate value. The differences so obtained must be added, and their sum (irrespective of sign), when divided by the corresponding number of scale-divisions, will furnish the desired value.

For an example of the amount of torsion, as measured from four twists of 90° each, see "Observations for Intensity-Oscillations" further on. Moistening the fibers with a small drop of glycerine will greatly reduce and equalize the torsion.

It appears from observations of the daily fluctuation of the declination that the mean of the extreme easterly and westerly positions in any one day approaches nearly (within half a minute) to the mean position of the day, as derived from hourly observations continued day and night. Since corrections to observed declinations to refer them to the mean of the day are generally very unsatisfactory, it is recommended to observe the declination for any one day at the epochs of the eastern magnetic elongation and of the western magnetic elongation and to take the mean position as representing the declination for that day. The epochs of extreme positions, as observed at Philadelphia, Washington, and Key West, apply, with comparatively small changes, to nearly all places within the United States and may be stated to be as follows: Referring to the north end of the magnet, the morning *eastern* elongation occurs, on the average, from May to September, inclusive, about 7½ a. m.; in March, April, and October, about 8 a. m.; in November, about 8½ a. m. and in December ,January, and February, about 9 a. m.; earliest time in August, about 7¼ a. m., latest in January, about 9 a. m. These epochs, however, are subject to great fluctuations and cannot be depended upon in any one case within one hour and frequently they cannot be recognized at all, either on account of the small range of the daily fluctuation—the amount of which in winter is but one-half, nearly, of the amount in summer—which is easily disguised by small irregularities, or on account of disturbances, which reach their maxima in September and October and generally are more predominant in winter than in summer. The afternoon *western* elongation occurs, on the average, about 1¼ p. m. from May to November, inclusive and about 1¾ p. m. in the remaining months; also, earliest in September—some minutes before 1 p. m.—and latest in January, about 1¾ p. m. The afternoon epoch is subject to *less* fluctuation than the morning epoch.

The following table will be found useful for correcting or reducing an observation of the declination taken at any time between 6 a. m. and 6 p. m. to the mean of the day (or to the mean of 24 hourly observations). It is, however, only approximate, since the tabular values are slightly variable in the eleven-year or solar-spot cycle; moreover they are varying more or less irregularly from day to day. For interpolation for any place in the United States we may consider that, roughly speaking, the greater the horizontal force the smaller the tabular values, or the range of the daily variation is nearly inversely proportional to the horizontal force. For comparison we have the horizontal force H at Toronto = 3.50, at Philadelphia = 4.16 and at Key West 6.74 nearly. No notice is taken of the annual inequality, which may amount to about one minute and a half, in maximo.

*Solar diurnal variation of the declination at Toronto, Canada, at Philadelphia, Pa. and at Key West, Fla.*

A + sign indicates a deflection of the north end of the magnet to the westward. A − sign, to the eastward.

| | 6 a. m. | | | 7 a. m. | | | 8 a. m. | | | 9 a. m. | | | 10 a. m. | | | 11 a. m. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. |
| | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| January | −0.7 | −0.6 | +0.1 | −1.3 | −1.2 | 0.0 | −2.7 | −2.1 | −1.1 | −2.9 | −2.5 | −2.4 | −1.5 | −1.6 | −2.7 | +0.4 | +0.3 | −1.4 |
| February | −1.6 | −1.2 | −0.1 | −2.0 | −1.9 | −0.3 | −2.9 | −2.5 | −1.1 | −2.8 | −2.5 | −2.0 | −1.5 | −1.5 | −2.0 | +0.5 | +0.2 | −1.2 |
| March | −2.3 | −1.8 | −0.8 | −3.5 | −2.9 | −1.9 | −4.7 | −3.7 | −2.4 | −4.5 | −3.4 | −2.2 | −2.5 | −1.8 | −1.4 | +0.7 | +0.6 | −0.1 |
| April | −3.4 | −2.6 | −1.5 | −4.6 | −3.5 | −2.8 | −5.0 | −4.0 | −3.1 | −4.0 | −3.4 | −2.2 | −1.3 | −1.5 | −1.1 | +2.0 | +1.1 | +0.4 |
| May | −5.2 | −3.7 | −2.0 | −6.0 | −4.7 | −3.4 | −5.8 | −4.7 | −3.4 | −4.2 | −3.2 | −2.1 | −0.6 | −0.8 | −0.4 | +3.1 | +1.9 | +1.1 |
| June | −5.3 | −3.9 | −2.2 | −6.4 | −5.0 | −3.5 | −6.2 | −5.1 | −3.6 | −4.7 | −3.8 | −2.4 | −1.7 | −1.2 | −0.9 | +2.0 | +1.7 | +0.9 |
| July | −4.5 | −4.2 | −2.3 | −6.5 | −5.4 | −3.6 | −6.3 | −5.4 | −3.6 | −4.9 | −4.0 | −2.5 | −1.8 | −1.5 | −0.7 | +1.8 | +1.5 | +0.9 |
| August | −5.2 | −4.7 | −2.3 | −6.9 | −5.7 | −4.5 | −6.9 | −5.5 | −4.4 | −4.8 | −3.7 | −2.8 | −0.5 | −0.6 | −0.4 | +3.1 | +2.9 | +1.6 |
| September | −3.9 | −3.5 | −1.8 | −5.2 | −4.5 | −3.6 | −4.8 | −4.5 | −3.6 | −3.0 | −2.8 | −2.3 | −0.6 | +0.1 | −0.4 | +3.7 | +3.2 | +1.5 |
| October | −1.8 | −1.3 | −0.6 | −2.7 | −1.7 | −1.9 | −3.7 | −2.2 | −2.3 | −3.0 | −1.9 | −1.8 | −1.1 | −0.8 | −0.5 | +1.7 | +0.8 | +0.7 |
| November | −1.3 | −1.2 | 0.0 | −1.8 | −1.7 | −0.5 | −2.9 | −1.9 | −1.4 | −2.8 | −1.5 | −1.7 | −1.3 | −0.4 | −1.3 | +1.1 | +1.1 | −0.3 |
| December | −0.6 | −0.7 | +0.3 | −0.9 | −1.0 | +0.2 | −1.5 | −1.4 | −0.9 | −2.0 | −1.6 | −2.0 | −1.6 | −1.1 | −2.2 | +0.3 | +0.3 | −1.4 |

| | Noon. | | | 1 p. m. | | | 2 p. m. | | | 3 p. m. | | | 4 p. m. | | | 5 p. m. | | | 6 p. m. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. | T. | P. | K.W. |
| | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ | ′ |
| Jan | +2.5 | +2.3 | +0.4 | +3.3 | +3.4 | +1.6 | +3.1 | +3.3 | +1.9 | +2.4 | +2.5 | +1.7 | +1.6 | +1.5 | +1.1 | +0.9 | +0.9 | +0.6 | +0.3 | +0.6 | +0.3 |
| Feb | +2.4 | +2.0 | +0.1 | +3.3 | +3.0 | +1.1 | +3.3 | +3.0 | +1.5 | +2.5 | +2.4 | +1.4 | +1.7 | +1.7 | +1.1 | +1.4 | +1.2 | +0.8 | +0.8 | +0.8 | +0.5 |
| Mar | +3.7 | +2.7 | +1.1 | +5.2 | +3.9 | +1.9 | +5.4 | +3.9 | +2.2 | +4.8 | +3.2 | +1.8 | +3.4 | +2.3 | +1.1 | +2.2 | +1.6 | +0.7 | +1.1 | +1.0 | +0.6 |
| Apr | +4.5 | +3.6 | +1.6 | +6.0 | +5.1 | +2.5 | +5.8 | +5.2 | +2.9 | +5.0 | +4.3 | +2.6 | +3.3 | +3.0 | +1.9 | +1.7 | +1.8 | +0.9 | +0.8 | +0.9 | +0.5 |
| May | +5.2 | +4.1 | +2.1 | +6.3 | +5.1 | +2.6 | +6.1 | +4.9 | +2.6 | +4.8 | +3.9 | +2.3 | +3.1 | +2.5 | +1.5 | +1.3 | +1.2 | +0.8 | +0.4 | +0.4 | +0.5 |
| June | +4.7 | +4.0 | +2.1 | +6.2 | +5.0 | +2.6 | +6.3 | +4.8 | +2.8 | +5.3 | +3.8 | +2.5 | +3.8 | +2.6 | +1.7 | +1.7 | +1.6 | +1.0 | +0.6 | +0.9 | +0.5 |
| July | +4.2 | +3.9 | +1.9 | +5.9 | +5.3 | +2.5 | +6.0 | +5.4 | +2.6 | +5.1 | +4.5 | +2.3 | +3.7 | +3.3 | +1.6 | +1.9 | +2.0 | +1.0 | +0.7 | +1.2 | +0.5 |
| Aug | +6.0 | +5.4 | +2.7 | +7.2 | +6.3 | +3.2 | +6.5 | +5.5 | +3.2 | +5.0 | +3.8 | +2.4 | +2.7 | +2.0 | +1.5 | +1.0 | +0.9 | +0.7 | +0.2 | +0.5 | +0.4 |
| Sept | +6.3 | +5.2 | +2.6 | +6.4 | +5.5 | +2.9 | +5.4 | +4.5 | +2.5 | +3.4 | +3.0 | +1.7 | +1.2 | +1.7 | +0.8 | +0.4 | +0.8 | +0.5 | −0.1 | +0.3 | +0.5 |
| Oct | +3.7 | +2.6 | +1.5 | +4.2 | +3.2 | +1.6 | +3.9 | +3.0 | +1.3 | +2.7 | +2.2 | +1.0 | +1.8 | +1.1 | +0.8 | +1.2 | +0.3 | +0.8 | +0.7 | −0.4 | +0.5 |
| Nov | +3.0 | +2.3 | +0.7 | +3.8 | +2.8 | +1.2 | +3.3 | +2.6 | +1.1 | +2.5 | +1.9 | +0.9 | +1.8 | +1.2 | +0.6 | +1.1 | +0.6 | +0.2 | +0.1 | +0.1 | 0.0 |
| Dec | +1.9 | +1.9 | −0.1 | +3.0 | +3.0 | +0.9 | +3.4 | +3.0 | +1.4 | +2.4 | +2.3 | +1.4 | +1.7 | +1.3 | +1.0 | +0.8 | +0.6 | +0.5 | 0.0 | +0.1 | +0.1 |

The Toronto results are derived from observations of five years ending June 30, 1848.

The Philadelphia results are derived from observations of five years ending June 30, 1845.

The Key West results are derived from observations of six years ending April, 1866.

For reducing observations to mean of day (24 hours) the signs of the tabular quantities must be *reversed.*

The following tables of the times and azimuths of Polaris *when at elongation* have been prepared for the benefit of those surveyors and others who may prefer to make use of the pole-star for their determination of the true meridian and whose instrumental outfit for the measure of the declination may be limited to a compass with sights or to a small theodolite with compass-needle attached and who may be without a chronometer.

The method was recommended to surveyors by Dr. Charles Davies in the revised edition of his work on surveying and a description of it still forms part of the instructions of the Commissioner of the General Land Office to the surveyors-general of public land of the United States (editions of 1855, 1871 and 1878). The tables given in these instructions have either become obsolete from lapse of time or are not sufficiently extended for future use. They were, therefore, recomputed and in their present form and with the rules given for interpolation will be found to possess greater accuracy than any similar tables previously published. The tables include all elongations whether occurring by day or night. Polaris can be observed in day time when the sun is not too high even with moderately powerful telescopes; besides, a complete table facilitates interpolation.

*Mean local time (astronomical, counting from noon) of the elongations of Polaris.*

[The table answers directly for the year 1885, for latitude +40° and for longitude 6 hours west of Greenwich.]

| Date. | Eastern elongation. | Western elongation. |
|---|---|---|
| | h. m. | h. m. |
| Jan. 1 | 0 35.3 | 12 24.6 |
| 15 | 23 36.1 | 11 29.3 |
| Feb. 1 | 22 29 0 | 10 22.2 |
| 15 | 21 33.7 | 9 27.0 |
| Mar. 1 | 20 38.5 | 8 31.8 |
| 15 | 19 43.4 | 7 36.6 |
| Apr. 1 | 18 36.4 | 6 29.7 |
| 15 | 17 41.4 | 5 34.7 |
| May 1 | 16 38.6 | 4 31.8 |
| 15 | 15 43.7 | 3 36.9 |
| June 1 | 14 37.1 | 2 30.3 |
| 15 | 13 42.2 | 1 35.4 |
| July 1 | 12 39.6 | 0 32.8 |
| 15 | 11 44.7 | 23 34.0 |
| Aug. 1 | 10 38.2 | 22 27.5 |
| 15 | 9 43.3 | 21 32.6 |
| Sept. 1 | 8 36.7 | 20 26.0 |
| 15 | 7 41.7 | 19 31.1 |
| Oct. 1 | 6 38.9 | 18 28.2 |
| 15 | 5 43.9 | 17 33.2 |
| Nov. 1 | 4 37.0 | 16 26.4 |
| 15 | 3 41.9 | 15 31.3 |
| Dec. 1 | 2 38.9 | 14 28.2 |
| 15 | 1 43.6 | 13 33.0 |

N. B.—To refer the tabular times to any year (limit about 10 years) subsequent to the epoch *add* $0^{m}.35$ for every year. For years previous to epoch *subtract* $0^{m}.35$ for every year.

To refer the tabular times to any other latitude (between the limits 25° and 50°) *add* $0^{m}.14$ for every degree south of 40°; *subtract* $0^{m}.18$ for every degree north of 40°.

To refer the tabular times to any year in a quadriennium, observe—

For first year after a leap year the table is perfect.
For second year after a leap year *add* . . . . $1^{m}.0$
For third year after a leap year *add* . . . . $2^{m}.0$
For a leap year and before March 1 *add* . . . $3^{m}.0$
And for remainder of the year *subtract* . . . . $1^{m}.0$

For any other than the tabular day *subtract* from the tabular time of elongation $3^{m}.94$ for every day elapsed.

It will be noticed that there occur two eastern elongations on January 9, and two western elongations on July 9.

*Azimuth (from the north) of Polaris, when at elongation, between the years* 1882 *and* 1895, *for different latitudes between* + 25° *and* + 50°.

| Lat. | 1882.0 | 1883.0 | 1884.0 | 1885.0 | 1886.0 | 1887.0 | 1888.0 | 1889.0 | 1890.0 | 1891.0 | 1892.0 | 1893.0 | 1894.0 | 1895.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| +25 | 1 27.4 | 1 27.1 | 1 26.7 | 1 26.4 | 1 26.0 | 1 25.7 | 1 25.3 | 1 25.0 | 1 24.6 | 1 24.3 | 1 23.9 | 1 23.6 | 1 23.2 | 1 22.9 |
| 26 | 28.1 | 27.8 | 27.4 | 27.1 | 26.7 | 26.4 | 26.0 | 25.7 | 25.3 | 25.0 | 24.6 | 24.3 | 23.9 | 23.6 |
| 27 | 28.9 | 28.6 | 28.2 | 27.8 | 27.5 | 27.1 | 26.8 | 26.4 | 26.0 | 25.7 | 25.4 | 25.1 | 24.7 | 24.3 |
| 28 | 29.7 | 29.4 | 29 0 | 28.7 | 28.3 | 27.9 | 27.6 | 27.2 | 26.8 | 26.5 | 26.2 | 25.8 | 25.4 | 25.1 |
| 29 | 30.6 | 30.2 | 29.9 | 29.5 | 29.1 | 28.8 | 28.4 | 28.0 | 27.6 | 27.3 | 27.0 | 26.6 | 26.3 | 25.9 |
| 30 | 31.5 | 31.1 | 30.7 | 30.3 | 30.0 | 29.6 | 29.3 | 28.9 | 28.5 | 28.2 | 27.8 | 27.5 | 27.1 | 26.8 |
| 31 | 32.4 | 32.1 | 31.7 | 31.3 | 30.9 | 30.5 | 30.2 | 29.8 | 29.4 | 29.1 | 28.8 | 28.4 | 28.0 | 27.6 |
| 32 | 33.4 | 33.0 | 32.7 | 32.3 | 31.9 | 31.5 | 31.2 | 30.8 | 30.4 | 30.1 | 29.7 | 29.3 | 29.0 | 28.6 |
| 33 | 34.5 | 34.1 | 33.7 | 33.3 | 33.0 | 32.6 | 32.2 | 31.8 | 31.4 | 31.1 | 30.7 | 30.3 | 30.0 | 29.6 |
| 34 | 35.6 | 35.2 | 34.8 | 34.4 | 34.0 | 33.6 | 33.3 | 32.9 | 32.5 | 32.1 | 31.8 | 31.4 | 31.0 | 30.6 |
| 35 | 36.7 | 36.3 | 35.9 | 35.5 | 35.2 | 34.8 | 34.4 | 34.0 | 33.6 | 33.2 | 32.9 | 32.5 | 32.1 | 31.7 |
| 36 | 37.9 | 37.5 | 37.1 | 36.7 | 36.4 | 36.0 | 35.6 | 35.2 | 34.8 | 34.4 | 34.0 | 33.6 | 33.2 | 32.9 |
| 37 | 39.2 | 38.8 | 38.4 | 38.0 | 37.6 | 37.2 | 36.8 | 36.4 | 36.0 | 35.6 | 35.2 | 34.8 | 34.5 | 34.1 |
| 38 | 40.5 | 40.1 | 39.7 | 39.3 | 38.9 | 38.5 | 38.1 | 37.7 | 37.3 | 36.9 | 36.5 | 36.1 | 35.7 | 35.3 |
| 39 | 41.9 | 41.5 | 41.1 | 40.7 | 40.3 | 39.9 | 39.5 | 39.1 | 38.7 | 38.3 | 37.9 | 37.5 | 37.1 | 36.7 |
| 40 | 43.4 | 43.0 | 42.6 | 42.2 | 41.8 | 41.4 | 41.0 | 40.5 | 40.1 | 39.7 | 39.3 | 38.9 | 38.5 | 38.1 |
| 41 | 45.0 | 44.6 | 44.1 | 43.7 | 43.3 | 42.9 | 42.5 | 42.0 | 41.6 | 41.2 | 40.8 | 40.4 | 40.0 | 39.6 |
| 42 | 46.6 | 46.2 | 45.8 | 45.4 | 44.9 | 44.5 | 44.1 | 43.6 | 43.2 | 42.8 | 42.4 | 42.0 | 41.5 | 41.1 |
| 43 | 48.3 | 47.9 | 47.5 | 47.0 | 46.6 | 46.1 | 45.7 | 45.3 | 44.9 | 44.4 | 44.0 | 43.6 | 43.2 | 42.7 |
| 44 | 50.1 | 49.7 | 49.3 | 48.8 | 48.4 | 47.9 | 47.5 | 47.1 | 46.6 | 46.2 | 45.8 | 45.3 | 44.9 | 44.4 |
| 45 | 52.0 | 51.6 | 51.1 | 50.7 | 50.3 | 49.8 | 49.4 | 48.9 | 48.5 | 48.1 | 47.6 | 47.1 | 46.7 | 46.2 |
| 46 | 54.0 | 53.6 | 53.1 | 52.7 | 52.2 | 51.8 | 51.3 | 50.9 | 50.4 | 50.0 | 49.5 | 49.0 | 48.6 | 48.2 |
| 47 | 56.2 | 55.7 | 55.2 | 54.7 | 54.3 | 53.8 | 53.4 | 52.9 | 52.5 | 52.0 | 51.5 | 51.0 | 50.6 | 50.2 |
| 48 | 1 58.4 | 1 57.9 | 57.5 | 57.0 | 56.5 | 56.0 | 55.6 | 55.1 | 54.6 | 54.2 | 53.7 | 53.2 | 52.8 | 52.3 |
| 49 | 2 00.8 | 2 00.3 | 1 59.8 | 1 59.3 | 1 58.8 | 1 58.3 | 1 57.9 | 57.4 | 56.9 | 56.5 | 56.0 | 55.5 | 55.0 | 54.5 |
| +50 | 2 03.3 | 2 02.8 | 2 02.3 | 2 01.8 | 2 01.3 | 2 00.8 | 2 00.3 | 1 59.8 | 1 59.3 | 1 58.8 | 1 58.4 | 1 57.9 | 1 57.4 | 1 56.9 |

7. *Observations for magnetic declination.*—The observations for declination, which consist in noting the scale-readings, may be made, say, every ten minutes or every quarter of an hour, commencing at a sufficiently early time in the morning to make sure of preceding and including the eastern elongation. When this phase is fairly passed and consequently the north end of the magnet has commenced its westerly motion, the observations may be discontinued, to be resumed again shortly after noon for the second epoch and to include the western elongation, as shown in the following example:

MAGNETIC DECLINATION.

[Station, Washington, D. C. Date, June 15, 1871. Instrument, theodolite-magnetometer No. 7. Observer, C. A. S. Mark reads at $6^h$ $10^m$, 242° 50 and 62° 49′.5. Line of detorsion, 276°. Magnet A suspended by two fibers, with scale erect.† Azimuth circle set to 244° 25′.0 and 64° 24′.5.]

| Time. | Scale-readings. | | Mean. | Remarks. |
|---|---|---|---|---|
| | Left. | Right. | | |
| A. M. | | | | |
| *h.* *m.* | *d.* | *d.* | *d.* | |
| 6 30 | 11.0 | 12.8 | 11.90 | Removed torsion-weight at $6^h$ $15^m$ and suspended magnet. |
| 45 | 11.8 | 12.2 | 12.00 | |
| 7 00 | 12.0 | 12.3 | 12.15 | |
| 15 | 12.2 | 12.5 | 12.35 | |
| 30 | 12.4 | 12.5 | 12.45 | Maximum. |
| 45 | 12.3 | 12.5 | 12.40 | |
| 8 00 | 12.1 | 12.3 | 12.20 | Suspended torsion-weight after this observation. |
| P. M. | | | | |
| 0 15 | 5.9 | 6.9 | 6.40 | Before commencing afternoon series turned torsion-circle to 264°; azimuth-circle as before. |
| 30 | 6.0 | 6.6 | 6.30 | |
| 45 | 6.2 | 6.5 | 6.35 | |
| 1 00 | 6.2 | 6.3 | 6.25 | Minimum. |
| 15 | 6.2 | 6.3 | 6.25 | |
| 30 | 6.3 | 6.7 | 6.50 | |

Pointing on mark: 242° 50′.0 and 62° 49′.5

* Increasing scale numbers correspond to decreasing circle readings.

| | *d.* | | | | *d.* |
|---|---|---|---|---|---|
| Mean reading of E. and W. elongations | 9.35 | | | and difference of readings | 6.20 |
| Axis of magnet reads | 7.30 | | | | |
| Reduction to axis | +2.05 = | | 5′.0 | | |
| Azimuth circle reads | | 244° | 24.8 | | |
| *Magnetic* north *meridian* reads | | 244 | 29.8 | | |
| Mark reads | | 242 | 49.9 | | |
| Mark, west of north | | 4 | 36.1 | ± 0′.1 | |
| *Astronomical meridian* reads | | 247 | 26.0 | | |
| Magnetic declination | | +2 | 56.2 | | |
| Reduction to mean of day | | + | 0.2 | | |
| Resulting magnetic declination, June 15, 1871 | | 2 | 56.4 | W. | |

We have, also, for this day the daily range 15′.1 and the turning hours about $7^h\ 30^m$ a. m. and $1^h\ 05^m$ p. m. Unless time be wanting it is customary to observe for declination, as above, on three generally consecutive days.

The observer's attention should be specially directed to the frequent examination of the plane of detorsion, since every change in the temperature or moisture of the air is apt to develop twist, which, if not removed, will injure the accuracy of the observations.

## II.—DETERMINATION OF THE MAGNETIC INCLINATION.

8. *Description of instrument.*—The inclination, or dip, is measured in the vertical plane passing through the magnetic meridian of the place and is the angle contained between a horizontal direction and the direction of a magnetic needle moving freely about a horizontal axis which is directed east and west magnetically. It is measured by means of a dip-circle and is considered + when the north end of the needle dips below the horizon. Thus in the northern magnetic hemisphere the dip will be noted + and in the southern magnetic hemisphere —.

In a plainly constructed circle, the graduation, which is directly read off opposite the ends of the needle, is generally not closer than quarter degrees or ten minutes and subdivisions are to be estimated. In the more elaborate instruments, like those made after the Kew pattern,* for instance, the needle does not swing in the plane of the graduated circle and the pointing at end-marks on the needle is done by the aid of two microscopes, with threads in the focus and the circle is read off to the nearest minute or half-minute by means of two verniers. The latter construction is advantageous only with well-balanced needles, having as perfectly cylindrical axles as can be made. The circles are also provided with means for determinining relative total intensity. For this purpose they are supplied with perforated or Lloyd needles for deflection by weights, and have a support for deflections by a plain so called intensity needle, specially supplied. Diameter of vertical and of horizontal circles about 13 cm.; length of needles, 9 cm.

9. *Adjustment of dip-circle.*—In adjusting the dip-circle, preparatory to observing, the following conditions should be satisfied as near as may be and the observations should be arranged so as to eliminate any small outstanding defects in the adjustment of the instrument: It should be leveled, or its vertical axis should be set truly vertical. The agate or steel plates supporting the needle should have their upper surfaces level; they should be of equal height and a horizontal tangent-plane to these surfaces should pass below the center of graduation at a distance equal to the radius of the axle or pivot of the needle. The zero graduation of the dip-circle should, for convenience, lie in or close to a horizontal plane passing through the center of the circle; also, the planes of the faces of the suspended needle and that of the circle should be truly vertical; and finally, the prolongation of the axle of the needle should pass through the center of graduation. For instruments provided with microscopes the following additional conditions should be satisfied: The microscopes must be focussed for distinct vision of the ends of the needle and for their focal threads; these threads should be placed in the line of collimation, and for the two microscopes, should be 180° apart; and, if produced, the threads should pass through the center of graduation To aid in these adjustments of the focal threads it is recommended to suspend in the vertical plane

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*See plate No. 37, illustrating this form of dip-circle.

of the face of the needle by means of a lump of bees-wax, a fine silk fiber lightly weighted at its lower end, so as to hang freely and accurately over the center of graduation.

To place the dip-circle in the plane of the magnetic meridian, we have two ways, either by the aid of an ordinary long compass-needle, which is supported on the top of the wooden frame of the instrument, or by means of the dipping-needle itself, which will point vertically when in the plane of the magnetic prime vertical. The former method is more expeditious; the latter can always be resorted to and consists in four readings of the azimuth-circle of the instrument when placed successively in the positions: face of circle south (magnetic), with face of needle south and face of needle north; next, face of circle north, with face of needle north and face of needle south; the mean reading + 90° and — 90° will then give the settings of the circle for the measure of the dip in the magnetic meridian. A more precise value will be found if the process is repeated, with the polarity of the needle reversed. The azimuth-circle is provided with two stops, against which the case with needle will abut; one for face of circle east, the other for face of circle west.

The needles, before magnetization, should balance perfectly, and those intended for the relative measure of total intensity, according to Dr. Lloyd's method, should be guarded as much as possible against any change in their magnetism.

It will be noticed that the mean resulting dip will, by the *reversal* of the *dip-circle*, be free of any small error in the level or the verticality of axis and eliminate any index error; that the *reversal* of the *face* of the needle on the agates will, like the first, free the result from effect of imperfection in its transverse balance and from non-coincidence of its geometrical and magnetic axes and that the *reversal* of the polarity of the needle will correct for any defect in the position of its center of gravity with respect to any longitudinal distance from the axis of rotation.

10. *Reversal of poles of dipping-needles.*—The needles which are exclusively used for the measure of the inclination should have their poles reversed at each place of observation and the results with polarity north and polarity south must be combined to a mean value. If exceptionally, from want of time, the polarity should not have been reversed at a station, the difference in results between polarity north and south, as found at stations which have nearly the same dip, may be applied as a correction. To reverse the polarity we may proceed as follows: fasten the needle in the reversing-block and, holding a bar-magnet in each hand, bring the *opposite* poles of the two bar-magnets close together at the middle of the needle so as to touch the same on both sides of the axle; the needle is supposed to be on a level plane and the bars are to be inclined outward about 25° or 35° to the horizon. They are then drawn slowly and steadily over the needle, carrying them *over* its ends and, after lifting them some inches above the level of the needle, bring them back to the middle position and move them again over the surface. This process may be gone through three times, when the upper face of the needle is turned down, in which position the magnetization is repeated as before. Care should be taken to have the motion exactly in the direction of the geometrical axis of the needle; the supporting-block usually has a ledge, along which the magnet can be drawn, closely touching it, which will insure a movement parallel to the axis of the magnetic needle. If its north end is to be changed to a south end, place the north (or marked) end over that end of the needle when magnetizing. The polarity as well as the face may be designated by means of the number or letter usually cut on the face-end of the needle. The reversing-bars should be carefully handled and should not be allowed to touch each other except at their opposite poles and when placed in the box the ends of opposite polarity should be connected by a soft-iron armature. If the reversal of the needle is to be repeated a short time after the operation, the method is only changed by using four instead of three passes over each face of the needle; if another reversal is needed shortly after, five passes would be required. This is done in order first to neutralize the existing magnetic polarity and then to give it the opposite polarity desired; if, however, one or more days have elapsed between a reversal, enough of magnetism of the needle has been lost to render any increased number of passes unnecessary. The number of strokes depends primarily on the strength of the bars and the relative size of the bars and needles. Should the bars have too much intensity and the needles be long, an irregular distribution of magnetism might be produced. Should the bars be of unequal intensity, it is recommended to exchange them in the hands, after performing one half of the operation of reversal, turning them at the same time end for end and completing the operation in the new position. When not in use and when observ-

ing for dip, the bar-magnets should not be kept nearer to the observer than about ten meters; but when observing for declination they should be kept at a greater distance. The needles should be carefully guarded against moisture, and after use be wiped dry with chamois skin.

11. *Observations for inclination or dip.*—The following example of a record of ordinary observations of the dip will show sufficiently the general arrangement. The readings in the second horizontal line are independent of those of the first, and between these observations the needle has always been lifted off its supports. If the position of the needle is recorded while slowly oscillating, it is customary to record the left and right extreme excursions and, in order to correct for diminution of arc, the mean of the reading of the first extreme and of its next return to it should be taken before combining with the reading of the opposite extreme. In this case the mean for the first extreme positions may be taken mentally and the second extreme is recorded under it; then follow the readings corresponding to the second line after the needle has been lifted off and let down again on the agate supports. The letters S. and N. in the form below stand for south (upper) and north (lower) end of the needle, when suspended.

It is recommended to observe the needle while slowly oscillating in preference to noting its position at rest, in which latter case the equilibrium may be influenced by any small irregularity in the axle at the point of contact, which, it may be supposed, would be passed over by an oscillating motion. Defects in the figure of the axle may also be recognized by irregularities in the oscillatory motion of the needle.

The introduction of position needles having a movable axle, which may be turned by means of a key to different positions, with a view of eliminating small defects in the figure of the axle, has, so far, not proved as satisfactory as was anticipated, owing to the difficulty of perfectly figuring the axle and centering the movable arbor; if such needles are used their polarity, after the first set of observations have been made, will be reversed and the observations will be concluded *before* turning to a new position.

*Magnetic dip.*

[Station. Washington, D. C. Date, November 10, 1853. Six-inch Barrow Dip Circle No. 2. Needle No. 1. Observer, S. H. Commenced 10<sup></sup>h 15m a. m.; concluded 10h 33m a. m.]

Mean, circle E. and W., 71° 13′.3

| POLARITY OF MARKED END NORTH. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Circle east. | | | | Circle west. | | | |
| Face east. | | Face west. | | Face east. | | Face west. | |
| S. | N. | S. | N. | S. | N. | S. | N. |
| ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| 71 24 | 71 08 | 71 08 | 71 31 | 71 08 | 70 50 | 70 56 | 70 42 |
| 26 | 03 | 08 | 31 | 00 | 58 | 54 | 42 |
| 71 25 | 71 05 | 71 08 | 71 31 | 71 04 | 70 54 | 70 55 | 70 42 |
| 71 15 | | 71 19.5 | | 70 59 | | 70 48.5 | |
| 71 17.3 | | | | 70 53.7 | | | |
| 71 05.5 | | | | | | | |
| POLARITY OF MARKED END SOUTH. | | | | | | | |
| Circle west. | | | | Circle east. | | | |
| Face west. | | Face east. | | Face west. | | Face east. | |
| S. | N. | S. | N. | S. | N. | S. | N. |
| ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| 71 12 | 71 17 | 71 05 | 71 05 | 71 41 | 71 30 | 71 43 | 71 18 |
| 11 | 17 | 04 | 04 | 45 | 25 | 44 | 20 |
| 71 11 | 71 17 | 71 05 | 71 04 | 71 43 | 71 27 | 71 43 | 71 19 |
| 71 14 | | 71 04.5 | | 71 35 | | 71 31 | |
| 71 09.2 | | | | 71 33.0 | | | |
| 71 21.1 | | | | | | | |
| Resulting dip.................................. 71° 13′.3 | | | | | | | |

Mean, circle W. and E., 1° 13′.3

NOTE.—The magnetic meridian was obtained by horizontal or compass needle, which was removed before commencing dip observations

*Specimen of record for finding plane of magnetic meridian by dipping-needle.*

| | Azimuth-circle. | |
|---|---|---|
| Circle south, needle south | 99° | 02′ |
| " " " north | 97 | 58 |
| Circle north, needle south | 278 | 52 |
| " " " north | 278 | 28 |
| Setting: 8° 40′ and 188° 40′ | 98 | 40 |

It is desirable that in the various positions of the circle and needle the extreme readings should keep within a range of 1° or 2°; the closer the better will be the final result.

12. *Observations of dip in various azimuths.*—For the purpose of testing the regularity of the figure of the axle of the needle and the freedom of the metal of the circle from any magnetism, we may observe dips in various azimuths; if $\theta_a$ = observed dip in magnetic azimuth $\alpha$, then the true inclination is found by

$$\tan \theta = \tan \theta \quad \cos \alpha.$$

The values of $\alpha$ may be successively changed by observations in azimuthal differences of about 10°.

13. *Observations of dip in two planes at right angles to each other.*—We may also obtain the true inclination, without the knowledge of the magnetic meridian, by observing the dip in any two vertical planes at right angles to each other and find the inclination by the formula

$$\cot^2 \theta = \cot^2 \theta_{\text{I}} + \cot^2 \theta_{\text{II}}$$

14. *Observations of dip by means of a loaded needle.*—But the best method would seem to be that of Mayer, proposed in 1814, which is peculiarly fitted for eliminating the effect of an irregularity in the figure of the pivots, since the dip can be found on almost any part of the circumference of the axle. This method consists in loading the needle (near its axis) and thus changing its direction. The new position is conditioned by the equilibrium of the magnetic force and that of gravity. The tilt may amount to 90° or more; and should the needle be deflected into the adjacent quadrant, the algebraic sign of the observed dip changes and must be attended to. For want of a better contrivance, a drop of sealing wax may be applied to the side of the needle near its axle, and observations may be made with the needle variously deflected by changing its quantity, or by letting it act at a different leverage. The ordinary rules for observing dip are adhered to, but special care must be taken that the weight be not changed in position in the act of reversing the polarity of the needle. This method of reduction may also be followed if ordinary needles differ as much as 3° or 4° in any of their separate results, either due to change of face or polarity.

Let $\theta_{\text{I}}$, $\theta_{\text{II}}$, $\theta_{\text{III}}$, $\theta_{\text{IIII}}$ be the observed dips, say, with face of needle E, face W and after change of polarity, with face W and face E, respectively, and

$$M = \cot \theta_{\text{I}} + \cot \theta_{\text{II}} \qquad N = \cot \theta_{\text{III}} + \cot \theta_{\text{IIII}}$$
$$m = \cot \theta_{\text{I}} - \cot \theta_{\text{II}} \qquad n = \cot \theta_{\text{III}} - \cot \theta_{\text{IIII}}$$

Then

$$\cot \theta = \frac{M\, n + N\, m}{2\,(m+n)}$$

The record, as given in the following example to this method, shows that the dip was noted while the needle was oscillating and that between the second and third horizontal lines the needle was lifted off the agates and let down again.

## *Magnetic dip by Mayer's method.*

Station, Washington, D. C. Date, September 22, 1856. Dip-Circle Barrow No. 5. Needle No. 2, loaded near axle. Observer, C. A. S. Commenced 11ʰ 30ᵐ; concluded 11ʰ 55ᵐ.]

| POLARITY OF MARKED END NORTH. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Circle east. | | | | Circle west. | | | |
| Face east. | | Face west. | | Face east. | | Face west. | |
| S. | N. | S. | N. | S. | N. | S. | N. |
| ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| −34 50 | −34 50 | 24 10 | 24 38 | −35 30 | −34 02 | 25 12 | 25 12 |
| −35 25 | −35 18 | 24 48 | 24 00 | −34 10 | −35 18 | 24 42 | 24 40 |
| −31 45 | −35 09 | 24 46 | 24 35 | −33 59 | −33 49 | 25 20 | 24 32 |
| −35 38 | −35 00 | 24 15 | 24 05 | −35 38 | −35 22 | 24 35 | 25 12 |
| −35 09.5 | −35 04.2 | 24 30.0 | 24 19.5 | −34 49.2 | −34 37.8 | 24 57.2 | 24 54.0 |
| −35 06.9<br>−34 43.5<br>$\theta_1$=−34 55.2 | | 24 24.7<br>24 55.6<br>$\theta_{11}$=24 40.2 | | −34 43.5 | | 24 55.6 | |

| POLARITY OF MARKED END SOUTH. | | | | | | | |
|---|---|---|---|---|---|---|---|
| Circle west. | | | | Circle east. | | | |
| Face west. | | Face east. | | Face west. | | Face east. | |
| S. | N. | S. | N. | S. | N. | S. | N. |
| ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| −41 00 | −41 55 | 29 30 | 29 27 | −42 14 | −41 03 | 29 55 | 29 09 |
| −42 10 | −40 48 | 30 30 | 30 23 | −41 02 | −42 08 | 29 20 | 29 41 |
| −42 10 | −40 50 | 30 35 | 30 29 | −42 09 | −42 05 | 29 29 | 29 18 |
| −41 00 | −41 51 | 29 25 | 29 20 | −41 10 | −41 10 | 29 48 | 29 35 |
| −41 35 | −41 1 | 30 00 | 29 54.8 | −41 38.8 | −41 36.5 | 29 38.0 | 29 25.8 |
| −41 28.0<br>−41 37.7<br>$\theta_{111}$=−41 32.8 | | 29 57.4<br>29 31.9<br>$\theta_{1111}$=29 44.6 | | −41 37.7 | | 29 31.9 | |

### *Reading of azimuth-circle for position of magnetic meridian.*

(This was determined before the needle was loaded.)

| | | |
|---|---|---|
| Magnetic prime vertical | 69° 00′ | by north polarity. |
| Magnetic prime vertical | 247 50 | by south polarity. |
| Mean, | 68 25 | |

### *Computation of the true dip.*

$$M=+0.74476$$
$$m=-3.60956$$
$$N=+0.62167$$
$$n=-2.87855$$

$$\because \theta=+71^\circ 19'.1$$

15. *Determination of the relative total intensity by means of the dip-circle in connection with deflecting weights, as devised by the Rev. H. Lloyd.*[*]—This method is known as Lloyd's *statical* method for measuring relative total intensity; and, although now superseded by his later device, which supplements it by an additional operation of deflections, which renders the result independent of any loss of magnetism of the needle during the time of a survey, the older method is, nevertheless, occasionally employed in cases where no modern dip-circle, with deflector attachments, is available. To free the results from the effect of slow loss of magnetism and to express them in absolute measure, it is necessary to occupy a base station where the total force is known from other means, and to make there observations both at the commencement and at the close of a magnetic survey. Special observations have also to be made to correct the results for difference of temperature during the observations.

The method essentially consists in balancing the magnetic force by that of gravity, and in observing the positions of a dipping-needle under the influence of the earth's magnetism alone and under the combined influence of magnetism and of a weight attached to the upper part of the needle at a fixed distance from its center. For this purpose the ordinary dip-circle is furnished with an additional needle, pierced in its longitudinal axis with three holes at each end for the insertion of platinum or German silver weights. This needle is known as a Lloyd or intensity needle, the magnetism of which must be carefully guarded against all disturbances, and the polarity of which is never reversed.

It is usual to determine the dip, $\delta$, by the dipping-needle, reversing the face of the needle, the face of the circle, and the polarity of the needle; but when using a Lloyd needle, where the last operation is inadmissible, the dip measured will in general require a small correction $\varepsilon$, found by

$$\sin\,\varepsilon=\rho\frac{\cos\zeta}{\cos\theta}\sin\,(\zeta-\theta)\quad\text{and}\quad\delta=\zeta+\varepsilon$$

where $\zeta$=inclination of the unloaded needle to the horizon;

$\theta$=its inclination when deflected by the weight (with minus sign when the north end has been tilted up beyond the horizontal line) and

$\rho$=a constant to be determined from corresponding values $\delta_0$, $\zeta_0$ and $\theta_0$ at a base station.

The value of $\varepsilon$ is nearly constant, except for great differences in the dips of the region under survey.

The true and deflected directions of the dipping needle being known, the magnetic total force $\varphi$ becomes known from the relation

$$\varphi\sin\,(\delta-\theta)=\beta\cos\theta$$

if the factor $\beta$ has been determined from corresponding values $\varphi_0$, $\delta_0$ and $\theta_0$ at the base station. The observed value of $\theta$ needs a correction for difference of temperature. This correction is most readily found by observations at the base station at very unequal temperatures from $\theta'-\theta=\alpha\,(t-t')$, where $t$=the observed and $t'$=the standard temperature, and $\theta$ and $\theta'$ the corresponding inclinations and $\alpha$ the temperature coefficient required.

For these observations it is desirable to select the hours of the day when the natural temperature reaches extreme values and it will be well to repeat them at a station where the magnetic conditions are most different from those at the first station.

The observations being thus corrected and reduced to a standard temperature, let $\delta_0$, $\theta_0$, $\varphi_0$ be the values at the base or comparison station and $\delta$, $\theta$, $\varphi$ corresponding values at any other station, then

$$\frac{\varphi}{\varphi_0}=\frac{\cos\theta_0\sin\,(\delta_0-\theta)}{\cos\theta_0\sin\,(\delta-\theta)}\quad\text{or}\quad\varphi=\mu_0\frac{\cos\theta}{\sin\,(\delta-\theta)}$$

introducing $\varphi_0$ in absolute measure, $\varphi$ becomes known expressed in the same unit.

It is desirable to make observations at the base station with more than one weight and using them at different distances from the center, in order to select that particular combination [to be carefully noted] which answers best for all stations; the method applies best for stations where the dip exceeds 45° and that weight should be selected which tilts the needle at nearly right angles to its first position. The observations at any one station may be arranged as follows, after making the ordinary adjustment of the instrument: First, for the dip, using the ordinary needle in eight positions, viz: face east and west, circle east and west, and polarity direct and reversed; second, using the Lloyd needle unloaded, face east and west with circle east (and, if time permits, also circle west); next, similar observations with the loaded needle, the temperature being recorded.

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[*] Transactions of the Royal Irish Academy, vol. xvii; also, report of the fifth meeting of the British Association for the Advancement of Science, at Dublin, in 1835. London, 1836.

As an example we add: At Savannah, Ga., which is the base station, we have on April 24, 26, 1852:

$$\delta_0 = 63^\circ\ 40'.0$$
$$\theta_0 = -32\ \ 19\ .6$$
$$\varphi_0 = 12.682$$
$$\text{hence } \log \mu_0 = 1.17395$$

At Washington, D. C., May 25, 1852, there was observed

$$\delta = 71^\circ\ 16'.1$$
$$\theta = -29\ \ 11\ .7$$

hence the total intensity at Washington $\varphi = 13.250$, also the horizontal intensity $H = 4.255$

16. *Determination of relative total intensity by means of the dip-circle, combining deflections by gravity and magnetism, by Dr. Lloyd's method.*—The more recently constructed Kew dip-circles are provided, as stated, with a deflector, to be applied on the outside of the circle, so that the axes of the deflected and deflecting needles are in the same straight line; with these instruments relative total intensity may be determined with great accuracy by a method* devised by Dr. Lloyd.

The method consists of two operations: By the first an ordinary dipping-needle is deflected by another so-called intensity-needle, their axes of rotation being in the same right line; by the second this intensity-needle, which is provided with small holes for the insertion of certain weights, is deflected by a weight and thus balanced against gravity. By a combination of these two processes the earth's relative total intensity can be found independent of the change of the magnetic intensity of the needle employed. The temperature of the intensity-needle is supposed the same during the short time needed to put it through the two operations; if not, a small correction will be required. To convert relative into absolute values observations must also be made at a base station where the magnetic intensity has been determined in absolute measure by means of a magnetometer. The method answers best for high (magnetic) latitudes, yet it has been found to give very satisfactory results on the coasts of Cuba and Yucatan.

The two special dipping-needles, designated Nos. 3 and 4, employed in the process, must be carefully guarded against any change of their magnetism, and their poles are never reversed.

At the *base station* let

$H_0$=known horizontal magnetic force in absolute measure.

$\theta$ =magnetic dip, + when north end of needle dips below the horizontal.

$u'_0$=half the difference of the readings of the dipping-needle (specially provided) when deflected by the Lloyd or intensity-needle in two positions of the poles, *i. e.*, directed alternately toward the magnetic north and south by a revolution of 180° of the movable frame carrying the deflector and the reading microscopes.

$\eta_0$ =observed dip of the Lloyd or intensity needle when loaded by a small weight at its upper end; then

$$u_0 = \theta_0 - \eta_0 \quad \text{and} \quad A = \frac{H_0}{\cos\theta_0}\sqrt{\frac{\sin u_0 \sin u'_0}{\cos\eta_0}}$$

For any other station let

$\theta$ $u'$ $\eta$=the observed quantities corresponding to those at the base station; also let $u = \theta - \eta$, then the total intensity will be given by

$$F = A\sqrt{\frac{\cos\eta}{\sin u \sin u'}}$$

and the horizontal intensity by

$$H = F\cos\theta.$$

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*The method is described by Sir E. Sabine in "A Manual of Scientific Enquiry," published by the English Admiralty; Art. Terrestrial Magnetism, pp. 105, 106, of 4th edition.—[London, 1871.]

## EXAMPLE.

### *Magnetic total intensity.*

Dr. Lloyd's method.

Base station, Washington, D. C.; date, January 8, 1879; instrument, Kew dip-circle by Casella, Coast and Geodetic Survey, No. 19; observer, S. M. A.

By the ordinary process, the dip by needles designated Nos. 1 and 2 was found $\theta_0 = 70^\circ\ 47'.5$

Needle No. 3 suspended, needle No. 4 deflecting; circle east; face of needle east; temp., 49° Fahr.

| Microscopes direct. | | Microscopes inverted. | |
|---|---|---|---|
| S. end. | N. end. | S. end. | N. end. |
| ° ′ | ° ′ | ° ′ | ° ′ |
| 61 23 | 61 09 | 82 24 | 82 13 |
| 22 | 13 | 30 | 20 |
| 23 | 10 | 28 | 16 |
| 22 | 09 | 36 | 25 |

$$u'_0 = \tfrac{1}{2}\,(82^\circ\ 24'.0 - 61^\circ\ 16'.4) = 10^\circ\ 33'.8$$

Needle No. 4 suspended and loaded by weight No. 1. Temp., 48° Fahr.

| CIRCLE EAST. | | | | CIRCLE WEST. | | | |
|---|---|---|---|---|---|---|---|
| Needle east. | | Needle west. | | Needle east. | | Needle west. | |
| S. end. | N. end. | S. end. | N. end. | S. end. | N. end. | S. end. | N. end. |
| ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ | ° ′ |
| −33 53 | −33 50 | −31 02 | −30 56 | −32 14 | −32 06 | −30 10 | −30 07 |
| 54 | 51 | −30 50 | 52 | 15 | 10 | −29 58 | −29 56 |

NOTE.—The — sign shows that the north end of the needle was tilted up above the horizontal.

hence $\eta_0 = -31^\circ\ 45'.2$ and $u_0 = +102^\circ\ 32'.7$; also, from observations with the magnetometer by means of oscillations and deflections, $H_0 = 4.372$ (in units of feet, grains, and seconds).

$$\begin{array}{rrl}
\log\sin u_0 = 9.98951 & & \\
\log\sin u'_0 = 9.26322 & & \\
\text{colog}\cos \eta_0 = 0.07042 & & \\
\hline
9.32315 & 9.66157 & \\
\log H_0 = & 0.64068 & \\
\log\sec\theta_0 = & 0.48280 & \\
\cline{2-2}
\log A = & 0.78505 & \text{and}\quad A = +6.0961 \text{ for weight No. 1.}
\end{array}$$

Similar observations taken at Havana, Cuba, March 13, 15, 16, 1879, gave the following results:

$$\begin{array}{rlr}
\theta = +52^\circ & 18'.1 & \log\cos\eta = 9.86185 \\
u' = +12 & 28.5 & \text{colog}\sin u = 0.00209 \\
\eta = -43 & 19.2 & \text{colog}\sin u' = 0.66552 \\
\cline{3-3}
\text{hence}\ u = +95 & 37.3 & 0.52946 \\
\cline{3-3}
 & & 0.26473 \\
 & & \log A = 0.78505 \\
\cline{3-3}
F = 11.215 & & \log F = 1.04978 \\
 & & \log\cos\theta = 9.78640 \\
\cline{3-3}
H = 6.8577 & & \log H = 0.83618
\end{array}$$

## III. ABSOLUTE AND RELATIVE MEASURES OF THE MAGNETIC FORCE.

17. *Units of measure of the magnetic force.*—It is usual, when accurate results are desired, to measure the horizontal component of the magnetic force by means of a portable unifilar magnetometer and the dip by means of a dip-circle, and to derive the total force by combining these results. In high magnetic latitudes, where the horizontal component is feeble in comparison with the vertical component, Lloyd's statical method, employing the dip-circle, as already explained, or his improved method by deflectors, are to be preferred. The latter method was employed with complete success even in the comparatively low latitudes of the Gulf of Mexico. Both methods give relative values for the total force. To measure the horizontal force by means of the magnetometer two distinct operations are required, known as "Observations of Deflections" and "Observations of Oscillations." Their combination will enable us to separate, in the observed force, that part which is due to the magnetism of the magnet from the other, which is due to the earth's magnetism. Either of these operations, but especially the latter, will determine relative horizontal intensity with great precision; and, when combined or when used in connection with a base station where the magnetic force is known, absolute results will be obtained. In the latter case the observer, after occupying the base station, should return to the same after the completion of his magnetic survey and again measure the magnetism of his magnet, which, in the interval, must have been carefully guarded against changes; the results must be corrected, if necessary, for loss of magnetism. Deflections give a measure of the *ratio* of the magnetic force of the (deflecting) magnet and that of the earth's horizontal component, whereas oscillations (of the same magnet) furnish a measure of the *product* of these two forces; hence they may be separated and each may finally be expressed in absolute measure.

The units for the measure of the earth's magnetic force commonly employed in England and the United States are the second of mean time, the foot (in the metric system, the millimetre), and the grain (in the metric system, the milligram). In statical measure the unit of magnetic force is the pressure of a unit mass under the influence of a unit force, which force would produce, if the mass be free to move during one second, a velocity of one unit (and not a velocity $g$ or force of gravity, which in latitude 45° is equal to 32.17 feet, or $9^{m}.806$, so commonly adopted in works on mechanics). This adopted unit of measure, considered dynamically, implies that the unit of accelerative force will produce unit velocity in unit of time. This unit of force is therefore $g$ times smaller than the unit of gravitation-force. Thus, supposing the horizontal force of the earth's magnetism to be (in British units) 4.36 at Washington in 1877, what is meant is that this force is equal to a pressure of a mass of 4.36 grains when under the influence of an attractive force which would produce during one second a velocity of one foot. The same, if expressed in ordinary units of gravitation-force, would be $\frac{4.36}{32.17}$, or 0.1355 grain of pressure under the earth's attraction.

The unit of magnetic force in the metric system is $\frac{1}{9806}$ of ordinary gravitation measure; hence in this respect the unit of magnetic force in the British system is to that of the metric system as 9806 : 32.17, or nearly 305 times greater than the latter. To change numerical measures of intensity expressed in units of the *metric system* into their equivalents expressed in C. G. S. or British Association measure, or in units of the centimetre, the gramme, and the second, we have only to shift the decimal point one place to the left. Thus, the horizontal force 4.36, given above for Washington, when expressed in Gaussian or metric units equals 2.010 and in C. G. S. units it becomes 0.2010 dyne.

The earth's magnetic energy acts upon a magnet as a couple, the attractive force exerted on one half of the magnet being equal and opposite in direction to the repulsive force on the other half.*

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*A magnetic pole of *unit strength* in the C. G. S. system is one which repels an equal pole at unit distance with unit force; that is, at a distance of 1 cm. with a force of 1 dyne.

The *strength* of the two opposite poles of a magnet is equal.

The *moment* of a magnet is its length multiplied by the strength of one of its poles, and a unit moment is one of a magnet of unit length with poles of unit strength.

The *intensity* of a magnetic field is the force which a unit pole will experience when placed in it.

The *intensity of magnetization* of a uniformly magnetized body is the quotient of its magnetic moment by its volume,

18. *Description and use of the magnetometer.*—There are two forms of unifilar magnetometers: that with a complete astronomical theodolite, or alt-azimuth, detached from the box in which the collimator-magnet is suspended, but generally on the *same* stand with it; and that which has the box with suspended magnet mounted centrally over, and firmly connected with, an azimuth-circle, the reading telescope being mounted eccentrically on supports. The first form, supposed to have been devised by Gauss and Weber, is the preferable one in field use; it admits of greater expedition, allows of greater ease in observing and is almost indispensable when the astronomical meridian has to be determined. With the magnet to the south of the theodolite, it readily admits of observations of the sun, for the determination of time and azimuth (also of latitude, if required), without interfering with the magnetic work proper. Deflections are read off on the scale of the collimator-magnet, and must be converted into angular measures. The second form,* supposed to have been given by Dr. Lamont, is capable of yielding deflection results of greater accuracy and is better suited for a fixed observatory, especially when declination disturbances also are to be observed, and at all stations where there is a large daily range in the declination. The angles of deflection are at once read off. In order to observe the azimuth-mark, the magnet and box have temporarily to be removed, which is unnecessary in the first form of the instrument. When observing deflections, the bar and consequently the deflecting magnet, remain fixed in the magnetic prime vertical, with the magnetometer with detached theodolite; but in the second form of the instrument as devised by Lamont the deflecting and deflected magnets always remain at right angles to each other.† Improvements have been made at the Coast Survey Office in the construction of magnetometers, with a special view of making them more portable than the older instruments, which were found unnecessarily large and heavy. In 1871 a 3-inch Casella theodolite was utilized for this purpose. The magnet (3 inches long and ¼ inch in diameter) and light wooden box, with glass tube, were first attached to the upper frame of the theodolite, but afterward to its stand, by which greater steadiness was secured. The relative horizontal intensity only could be measured by means of oscillations. In October, 1874, a similar instrument was fitted up by the writer, for use in South America, with 2 magnets, mass-ring, and deflecting bar for absolute measure, the magnets being only about 1⅓ and 1½ inches in length. In the year 1877 several instruments were constructed of the kind known as combination instruments, with 4-inch theodolites and magnets, 1.50 and 1.84 inches in length, respectively; diameter, 0.3 inch. One of these instruments is presented in the accompanying plate, No. 36. The upper part of the theodolite can be removed and the magnet-box placed on its azimuth-circle. The operations for either construction of the instrument are essentially the same and the simple modifications necessary in using one or the other form in observing and computing will be specially noted under the appropriate heads of the work. When observing for time and for duration of oscillations, a mean-time box-chronometer is most convenient for use; the observer will himself take up the beat (half second) and estimate fractions of seconds. For a traveler, who dislikes to be much incumbered, a pocket-chronometer is much to be preferred, but the counting of the beats, generally five in two seconds, requires some previous practice. It is recommended to take up an even beat—say at 0, 10, 20, 30, &c., seconds—and count only the even beats, repeating the letters *a b c d* in the intervals; thus, 10 *a b c d*, 12 *a b c d*, 14 *a*, &c. The letters are afterward converted into their equivalents of time; thus, 14 *c* would be $15^{s}.2$

19. *Observations of deflections.*—The instrument being adjusted as for observations of declination, attach the deflecting bar, suspend the shorter of the two magnets as generally supplied for each instrument; the line of detorsion having been placed in the magnetic meridian, insert the copper damper, raise the suspended magnet to the horizontal level of the deflecting (or long) magnet, put

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and unit intensity of magnetization in the C. G. S. system is one in which 1 cubic cm. of its volume has a magnetic moment equal to unity.

The force experienced by a magnet when placed in a magnetic field is *a couple*, and is equal to the product of the moment of the magnet by the intensity of the field, supposed uniform; it is a maximum when the axis of the magnet is at right angles to the lines of force in the field, it is zero when the magnetic axis lies in the direction of the force.

* See plates Nos. 34 and 35, containing representations of these two kinds of magnetometers.

† In this case, the bar and box turning on the center of the azimuth-circle, a measurable amount of *induced magnetism* is developed in the deflector when inclined to the magnetic prime vertical. In the form of instrument given by Gauss and Weber the deflector is not subject to the earth's inductive action.

the carrier at the proper distance on the bar and, after placing the intensity (or long) magnet* centrally on it, commence making the observations as indicated in the following scheme:

HORIZONTAL INTENSITY. DEFLECTIONS.

### FORM 1.

*Magnetometer with detached theodolite. Deflecting magnet in the magnetic prime vertical.*

[Station, Hampton. Date, July 11, 1862. Magnet $C_{32}$ deflecting. Magnet $S_8$ suspended. Observer, N. N.]

| Magnet. | North end. | Time. | Temperature. $t$. | Scale-readings. | Alternate means. | Differences. | Distance. |
|---|---|---|---|---|---|---|---|
| | | h. m. | ° | | | d. | |
| West. | W. | 10 22 | 78.8 | 20.2 | | | $r$ = 2 feet; log $r$ = 0.30103 |
| | E. | | | 133.5 | 20.30 | 113.20 | |
| | W. | 33 | 79.0 | 20.4 | 133.55 | .15 | |
| | E. | | | 133.6 | | | |
| | | 10 27.5 | 78.9 | | | 113.18 | |
| East. | E. | 10 26 | 79.0 | 133.0 | | | |
| | W. | | | 20.0 | 133.05 | 113.05 | |
| | E. | 10 29 | 79.0 | 133.1 | 19.95 | .15 | |
| | W. | | | 19.9 | | | |
| | | 10 27.5 | 79.0 | | | 113.10 | |
| Means | | 10 27.5 | 79.0 | | $2u =$ | 113.14 | |

†Reduction: $\frac{m}{H} = \frac{1}{2} r^3 \tan u \left(1 - \frac{P}{r^2}\right)$

| Torsion-circle. | Scale. | Differences. | | | Logarithms. |
|---|---|---|---|---|---|
| ° | d. | d. | | | |
| 83 | 76.5 | 2.7 | $u =$ | $56^d.57$ | 1.75259 |
| 173 | 79.2 | 5.6 | $1^d =$ | $2'.843$ | 0.45378 |
| 353 | 73.6 | 2.9 | $1 + \frac{h}{f}$ | | 0.00064 |
| 83 | 76.5 | | | | |
| $\frac{1}{4} \Sigma$ or mean $= v =$ 2.80 d. | | | $u =$ | $161'.07$ | 2.20701 |
| | | | | $= 2° 41'.07$ | |
| | | Logarithms. | $\tan u$ | | 8.67106 |
| | | | $r^3$ | | 0.90309 |
| $v' = -7'.96$ | | | $\frac{1}{2}$ | | 9.69897 |
| $5400' + v'$ | | 3.73303 | $1 - \frac{P}{r^2}$ | | 0.00040 |
| 5400 (ar. co.) | | 6.26761 | | | |
| $1 + \frac{h}{f}$ | | 0.00064 | $\frac{m}{H}$ | | 9.27352 |

NOTE.—The order of time indicated above by the several positions of the magnet is designed to correct for changes in declination during the observations of deflections.

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[*] A vertical plane passing through its axis should also pass through the line of suspension of the shorter magnet.

[†] For explanation of formula see further on.

HORIZONTAL INTENSITY. DEFLECTIONS.

### FORM 2.

*Theodolite magnetometer. Deflecting and deflected magnets at right angles to each other.*

[Station, Washington, D. C. Date, May 16, 1867. Magnet A deflecting. Magnet B suspended. Distance, $r = 1\frac{1}{8}$ feet. Log $r = 0.06695$
Observer, C. A. S.]

| Magnet. | North end. | Circle-readings. | | | | Circle-readings. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | No. | A | B | Mean. | No. | A | B | Mean. |
| | | | ° ′ | ′ | ′ | | ° ′ | ′ | ′ |
| East. | E. | 1 | 250 40.5 | 40.5 | 40.50 | | | | |
| | W. | | | | | 2 | 237 29.5 | 29.0 | 29.25 |
| | E. | 3 | 40.5 | 40.0 | 40.25 | | | | |
| | W. | | | | | 4 | 29.0 | 28.5 | 28.75 |
| | E. | 5 | 42.0 | 42.0 | 42.00 | | | | |
| | | | | Mean | 40.92 | | | | 29.00 |
| West. | W. | | | | | 6 | 237 32.5 | 32.0 | 32.25 |
| | E. | 7 | 250 32.0 | 31.5 | 31.75 | | | | |
| | W. | | | | | 8 | 32.5 | 32.5 | 32.50 |
| | E. | 9 | 31.0 | 31.0 | 31.00 | | | | |
| | W. | | | | | 10 | 33.0 | 32.5 | 32.75 |
| | | | | Mean | 31.37 | | | | 32.50 |

‡ Reduction: $\frac{m}{H} = \frac{1}{2} r^3 \sin u \left( 1 - \frac{P}{r^2} \right)$

| | | Logs. |
|---|---|---|
| Magnet E., $2u$ = 13° 11′.92 | $\frac{1}{2}$ | 9.69897 |
| Magnet W., $2u$ = 12° 58′.87 | $r^3$ | 0.20085 |
| Mean = 13° 05′.40 | Sin $u$ | 9.05684 |
| $u$ = 6° 32′.70 | $1 - \frac{P}{r^2}$ | 0.00136 |
| Time of commencing, 3 *h.* 29 *m.* Temp., 63°.5 Fah. | Induction* | 0.00009 |
| Time of ending, 3 45 Temp., 65.8 Fah. | | |
| 64.65 | $\frac{m}{H}$ | 8.95811 |

The preceding forms are arranged for determining the angle of deflection ($u$) by which the intensity-magnet, acting at a given distance, $r$ (expressed in feet), deflects the suspended magnet from the magnetic meridian and for determining the ratio of the magnetic force ($m$) of the deflecting magnet to that of the earth's horizontal component (H).† For the case of the deflector remaining in the magnetic prime vertical we have, with sufficient precision

$$\frac{m}{H} = \frac{1}{2} r^3 \tan u \left( 1 - \frac{P}{r^2} - \frac{Q}{r^4} \quad . \quad . \quad . \right)$$

for the case of the magnets remaining at right angles

$$\frac{m}{H} = \frac{1}{2} r^3 \sin u \left( 1 - \frac{P}{r} - \frac{Q}{r^4} \quad . \quad . \quad . \right)$$

where the terms $\frac{Q}{r^4}$, &c., may be omitted as too small to affect sensibly ordinary observations.

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* For method of determining the effect of induction and example of its application, see Coast Survey Report of 1869, Appendix No. 9. From a large number of magnets tested at the Kew Observatory, the extreme values for the induction-coefficient $\mu$ were .00042 and .00008, the average value being about .00021. [Proc. Roy. Soc., No. 181, May, 1877.] Unless great accuracy is required, the effect of induction may be neglected as too small.

† The magnetic moment of the *deflected* magnet does not enter here, since it disappears in the ratio $\frac{m}{H}$.

‡ For explanation of formula see below.

The first form requires the torsion of the suspension to be measured and to be corrected for; in the second form no twist is developed. The coefficient P, depending upon the distribution of magnetism within the deflecting magnet, must be ascertained experimentally by means of deflections at two or three distances, and at least twenty-five independent measures should be made for its numerical value; it will generally be found to have a negative sign, provided the magnets have their proper proportions of length, viz: short magnet to long magnet, as 1 to 1.224

To find P, let $A=$value of $\frac{m}{H}$ for the shorter distance $r$ and $A_1=$ value of $\frac{m}{H}$ for the longer distance $r_1$, then

$$P=\frac{A-A_1}{\frac{A}{r^2}-\frac{A^1}{r_1^2}}$$

If for any two consecutive sets of observations the temperature of the intensity-magnet is not the same, a correction for difference of temperature has first to be applied[*] to the observed angle of deflection. It may be done by means of the expression

$$\sin u=\frac{\sin u_0}{1-(t_0-t)q}$$

where $u_0 =$ observed angle of deflection of first set at temperature $t_0$;
$u =$ corrected angle in order to refer it to the standard temperature $t$ of the second set;
$q =$ temperature coefficient, to be determined from a series of observations of deflections, at a fixed distance, but at various temperatures.

For the case of the deflector in the magnetic prime-vertical we change in the formula sin into tan.

The coefficient Q, depending on the fourth power of $r$, may be neglected. The two distances $r$ and $r_1$ (to be measured from the middle of the magnets) may be in the ratio of 1 to $\sqrt{2}$ nearly, but not to exceed 1 to $\sqrt{3}$; or, for convenience, the second distance may be one-half greater than the first, but the shorter distance should not be less than about four times the length of the deflecting magnet. The correction for induction in Form 2 may be neglected in all cases where extreme accuracy is not required. In observing with the magnetometer and attached theodolite, we may save time by noting the two extreme scale-readings of an oscillation, instead of waiting for the magnet to come to rest; and in Form 2, we can also reduce the time of observation by setting the azimuth-circle beforehand nearly to the reading corresponding to the particular position of the magnet and afterward perfecting the pointing on the middle division by the azimuth or slow motion-screw. The scale of the deflecting bar[†] should be examined for graduation and eccentricity errors and corrected for them if necessary. When using a magnetometer with detached theodolite, the angular value of the scale of the de-flected magnet must be ascertained with great precision and, in general, special attention is to be paid to the temperature of the intensity-magnet, which must be the same, or be reduced to the same, temperature during the observations of deflections and oscillations. These two operations should, therefore, always immediately follow each other.

20. *Observations of oscillations.*—The instrument being adjusted and the intensity (long) magnet[‡] suspended without twist, with scale horizontal, and the copper damper removed, the observer will arrange his scheme for observing the duration of a certain number of oscillations, from which the time of one oscillation is to be deduced. The bulb of the thermometer to indicate the temperature

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For greater accuracy, the values of A and $A_1$ require also to be corrected for effect of induction in that form of instruments giving the *deflection-angle* directly. See "On Induction," Coast Survey Report of 1869, Appendix No. 9.

[†] A wooden bar is preferable to one of brass, on account of its greater lightness and less change of length with change of temperature.

[‡] This magnet generally serves also for observations of declination, but it may be preferable to make use of the *short* or deflection magnet when observing for declination and to remagnetize the same from time to time in order to keep it in a strong condition. Magnets at first part rapidly with their magnetism, but when 15 or 20 years old their annual loss becomes very small. At the end of 20 years one of our magnets still retained two-thirds of the magnetism that it had at the end of the first year.

of the magnet is put inside the box, the stem projecting outside. The mean-time chronometer,§ whose rate must be known, is placed at a safe distance below the telescope, allowing, however, the observer to take up the time, *i. e.*, pick up the beat, without changing his place.

With the magnet at rest, the vertical thread of the telescope should point nearly to the reading on the scale of the magnetic axis, or to the center division. Care must be taken that the magnet have no up and down vibrations; a horizontal motion is then given to it by means of a small magnetized piece of steel, sufficient to make it oscillate for about twenty or twenty-five minutes before coming to rest. The oscillations are counted as follows: Suppose the center division of the scale to pass from apparent right to left, call its first transit over the line of collimation of the telescope 0, and note the time (the minute having previously been noted, the second is added without taking the eye off the telescope); its next transit will be from left to right and is called 1, the next following one from right to left is called 2, and so on until the tenth transit is observed, when the time is again noted, for which purpose the beat of the chronometer has to be taken up in the usual manner. The duration of ten oscillations being thus approximately known, the intervals and whole number of oscillations to be observed can be properly arranged. With the light magnets now in use, two fibers and for those used in connection with 3-inch Casella theodolites, even a single fiber suffices for the suspension. The best arrangement yet devised for ordinarily observing oscillations is the following: Begin with apparent motion of the magnet, say, from right to left, and note for a certain number of oscillations the times of, say, three transits; then take an equal number from left to right, to be followed, after an interval of a few minutes (of rest to the observer), in order to get the duration for, say, one hundred oscillations, by a similar set of transits from right to left; and conclude finally with an equal number of transits from left to right. It will be noticed that for even numbers of oscillations the apparent motion is from right to left, for odd numbers the reverse. We thus provide experimentally for any effect of a change in the declination during the observations, the final mean duration of one oscillation being unaffected by any such change. It is advisable not to extend the entire time consumed in a set of observations beyond a quarter of an hour and to make the interval between any two consecutive observations (the magnet swinging again in the same direction) between one-third and two-thirds of a minute. This gives ample time to take up the beat of the chronometer, which is done, say, ten seconds before the expected time of transit in order to await it deliberately. The arrangement for a particular case is shown in the form given below; here the three intervals (rough ones only) of $39^s$, $43^s$ and $3^m\ 12^s$ are known beforehand and must be mentally added to the observed time in order to be prepared for the next following transits. With the time of a transit only roughly known, the observer will not be biased in his estimation of the observed fraction of a second. For each particular magnet, depending mainly on its mass and magnetic intensity, a special scheme must be devised, guided by the principles as explained above; but the same scheme may be adhered to for a number of stations, unless the survey extends over a space within the limits of which the earth's horizontal force has widely different values. Special attention is to be paid to the correct noting of the temperature and the observations must be accompanied by measures of the torsion. The correction for induction may be omitted except when great accuracy is demanded; it arises from the fact of the magnet having greater force, by induction, when suspended in the magnetic meridian, than in the positionat right angles to it (as in deflections). On the subject of induction, see Coast Survey Report of 1869, Appendix No. 9.

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§ If sidereal, we simply consider it as a mean-time chronometer with a large rate and correct for it accordingly.

HORIZONTAL INTENSITY. OSCILLATIONS.

[Station, Washington, D. C. Date, August 12, 1871. Magnet A suspended. Inertia ring, No. — (not used). Chronometer, Park. & Frod., 1216. Daily rate,* $-1^s.75$ on mean time. Observer, C. A. S.]

| No. of oscillations. | Time. | Temperature. $t'$ | Extreme scale-readings. | | Time of 100 oscillations. |
|---|---|---|---|---|---|
| | h. m. s. | ° | | | m. s. |
| 0 | 11 28 24.0 | 79.0 Fah. | 0.0 | 18.8 | |
| 10 | 29 03.0 | | | | |
| 20 | 42.2 | | | | |
| 31 | 30 25.1 | | | | |
| 41 | 31 04.2 | | | | |
| 51 | 43.2 | | | | |
| | | 79.5 | 1.8 | 16.8 | |
| 100 | 34 55.2 | | | | 6 31.2 |
| 110 | 35 34.3 | | | | 31.3 |
| 120 | 36 13.5 | | | | 31.3 |
| 131 | 56.2 | | | | 31.1 |
| 141 | 37 35.3 | | | | 31.1 |
| 151 | 38 14.2 | 80.0 | 4.0 | 14.8 | 31.0 |
| | Means | 79.5 | | | 6 31.17 |

Coefficient of torsion. Value of one scale-division = 2'.90

| Torsion circle. | Scale. | | Mean. | Differences. | $v'=2'.75$ | Logarithms. |
|---|---|---|---|---|---|---|
| ° | | | | | | |
| 300 | 8.8 | 11.2 | 10.0 | | | |
| | | | | 1.0 | 5400'+v' | 3.73261 |
| 30 | 7.5 | 10.5 | 9.0 | | | |
| | | | | 1.9 | 5400 (ar. co.) | 6.26761 |
| 210 | 9.8 | 12.0 | 10.9 | | | |
| | | | | 0.9 | | |
| 300 | 9.2 | 10.8 | 10.0 | | | |
| | | | | | $1+\frac{h}{f}$ | 0.00022 |
| ¼ Σ or mean = v = | | | | 0.95 | | |

*Calculation*† *by*

$$T^2=T'^2\left(1+\frac{h}{f}\right)\left(1-(t'-t)\,q\right)$$

| | | s. |
|---|---|---|
| Observed time of 100 oscillations ...... | = | 301.17 |
| Time of one oscillation.................. | = | 3.9117 |
| Correction for rate...................... | =− | 0.0001 |
| | T'= | 3.9116 |

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* Gaining rate is indicated by a minus sign.

† For explanation of formulæ see further on.

*Computation of the earth's horizontal component.*

$$H=\frac{\pi^2 M}{m\,T^2}$$

| | | | | |
|---|---|---|---|---|
| | | | | Logarithms. |
| | $q$ | 0.00027 | $T'$ | 0.59235 |
| † | $t'-t$ | +0.33 | | |
| | $(t'-t)\,q$ | 0.00009 | $T'^2$ | 1.18470 |
| | | | $1+\frac{h}{f}$ | 0.00022 |
| | $1-(t'-t)\,q$ | 0.99991 | $1-(t'-t)\,q$ | 9.99996 |
| | | | Induction* | 0.00079 |
| | | $m\,H=\frac{\pi^2 M}{T^2}$ | $T^2$ | 1.18567 |
| | | | $\pi^2$ M | 1.40062 |
| | | | $m$ H | 0.21495 |
| | | | $m$ | 9.57516 |
| | | | 4.3630=H | 0.63979 |
| | | | † $\frac{m}{H}$ | 8.93537 |
| | | | $m$ H | 0.21495 |
| | | | $m^2$ | 9.15032 |
| | | | 0.3760=$m$ | 9.57516 |

* See foot-note to Art. 19, Form 2 of deflections.

† From observations of deflection, date, August 12; $t$=79°.17 Fah.

Let H=the horizontal component of the earth's magnetic force; $m$=the magnetic moment of the intensity-magnet; M=its moment of mass (inclusive of stirrup and balancing ring,‡ if any); T=the time of one oscillation; then, from observations of oscillations, we have the expression for the product

$$m\,H=\frac{\pi^2 M}{T^2}$$

where $\pi=3.14159$

The observations of deflections give the ratio $\frac{m}{H}$ and the observations of oscillations the product $m$ H; $m$ and H can therefore be eliminated from the two equations, as shown in the preceding example.

To determine M, a truly-turned brass or bronze ring of known dimensions and weight (about equal to that of the magnet) is placed on the magnet. It is correctly centered by means of two wooden centering-blocks and when suspended must remain in a horizontal position. The number of suspension fibers must be doubled for the purpose. In this position a set of oscillations is observed similar in arrangement to that already explained; and if $T_1$ be the time of one oscillation of the loaded magnet, and $M_1$ the moment of mass of the ring, then

$$M=M_1\left(\frac{T^2}{T_1^2-T^2}\right)$$

A series of not less than thirteen *consecutive* sets of observations of oscillations, with the magnet *alternately* unloaded and loaded, is to be made, each set duly corrected for torsion, rate of chronometer and difference of temperature, from which the value of M is deduced. These results are to be combined with a view of eliminating the effect of changes in H during the observations; thus the mean of sets 1 and 3 is used with set 2, the mean of 3 and 5 with 4, &c., the first and last sets being alike either with magnet unloaded or loaded. As the torsion changes with the weight, observations for torsion must also be made with the loaded magnet. To find $M_1$ let $r$ and $r_1$ represent the inner and outer radii, expressed in decimals of a foot and $w$ the weight of the ring in grains, then

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‡This small balancing-ring must remain in the same position in all observations of oscillations; but its use should be avoided, if at all possible.

$$M_1 = \tfrac{1}{2}\,(r^2 + r_1^2)\,w$$

In reducing temperature of ring to standard temperature, it suffices to assume the ordinary coefficient of expansion for brass or bronze .0000105 for Fah., or .0000189 for the Centigrade scale.

The values of log $\pi^2$ M should be tabulated for different temperatures; we have

$$M = M_0\,[1 + 2\,e\,(\tau - \tau_0)]$$

where for hard-tempered steel $e$=.0000068 Fah., or .0000122 for Centigrade scale.

The reduction of the time of an oscillation to an infinitesimal arc is generally so small as not to affect the magnetic results. If $a$ and $a'$ express the initial and terminal semi-arcs of an oscillation (in parts of the radius), then the corrected value for $T^2$ will be

$$\left(1 - \frac{a\,a'}{16}\right)^2 T^2$$

This correction can be avoided by swinging only through small arcs.

21. *Correction for inequality of temperature.*—In general, when the temperature of a magnet rises there is a corresponding weakening of its effective magnetism and when its temperature falls there is an increase of magnetism. To reduce the measures of deflections and oscillations to the same temperature, let $t$ = the temperature of the magnet when deflecting; $t_1$ = its temperature when oscillating; $q$=the change in magnetic moment of magnet for a change in temperature of 1° Fahrenheit, then the coefficient to be applied to $T^2$ to reduce to temperature of deflections is equal to $1 - (t' - t)\,q$, as shown in the example. The value of $q$ is not constant, but, for a moderate range of temperature, may be taken as constant; it must be obtained experimentally, either from oscillations or from deflections, at various temperatures, but the magnet should not be subjected to a greater range of temperature than from about 32° to 100° Fahrenheit. These observations must be conducted by the alternate use of a jacket of ice and of hot water, or by the aid of extreme natural temperatures; ample time must, however, be given to the magnet to establish again an equilibrium in its magnetism; all *rapid* changes from cold to hot (or *vice versa*) will give decidedly erroneous values for $q$.

Supposing not less than three consecutive series of observations of deflections for finding a value of $q$ and the first and third series to be at nearly the same temperature, with their results combined to a mean, and the second or intermediate series at a greatly different temperature, then $q$ may be found, with sufficient precision, by the expression

$$q = \frac{a\,n\cot u}{t - t_0}$$

where $a$ = the arc value of one division of the scale of the suspended magnet in terms of the radius; $n$ = the difference of scale-readings corresponding to the difference of temperature $t - t_0$; and $u$ = angle of deflection at the lower temperature $t_0$. In every case the arrangement must be such as to eliminate, as far as possible, any effects of changes in declination and intensity during the observations. If other instruments are available, it is best to correct the readings for observed changes in declination and intensity.

### *Example of observations of deflections for value of q of magnet H.*

[Washington, D. C. Magnetic Observatory. J. S. H., observer. April 14, 1856. Magnet $C_{17}$ suspended. Magnet H deflecting at a distance of 21 inches to the east of suspended magnet. Mean declination-reading* of the day, $62^d.4$ One scale-division of $C_{17} = 2'.80$]

| Time. | Number of sets. | Declination-reading.* | Scale-reading of $C_{17}$, mean of five observations. | Mean minus observed declination. | Correction for change in declination. | Reading of $C_{17}$ corrected. | Observed temperature, Fahrenheit. |
|---|---|---|---|---|---|---|---|
| *h. m.* | | *d.* | *d.* | *d.* | *d.* | *d.* | ° |
| 10 02 a. m. | 1 | 59.3 | 28.82 | +3.1 | −1.11 | 27.71 | 44.0 |
| | 2 | 59.9 | 28.84 | 2.5 | 0.89 | 27.95 | 57.3 |
| | 3 | 60.5 | 29.07 | 1.9 | 0.67 | 28.40 | 73.1 |
| | 4 | 60.9 | 29.15 | 1.5 | 0.54 | 28.61 | 87.9 |
| | 5 | 61.3 | 28.73 | 1.1 | 0.39 | 28.34 | 74.3 |
| | 6 | 61.8 | 28.21 | 0.6 | 0.22 | 27.99 | 57.3 |
| | 7 | 62.2 | 27.64 | 0.2 | 0.07 | 27.57 | 42.8 |
| | etc. | | | | | | |

* Brooke's declinometer; 1 division of scale = 1′.

| | | |
|---|---|---|
| | | *d.* |
| Reading of $C_{17}$ before introducing H, | | 149. 4 |
| Reading of $C_{17}$ during deflection | | 28. 0 |
| Reading of $C_{17}$ after removing H | | 149. 3 |
| Angle of deflection | $5^\circ\ 39'.6=$ | 121. 3 |

The above partial results, which form but a portion of the observations taken, may be arranged as follows:

| Set number | Mean temperature. | Mean reading of $C_{17}$. | Differences in | |
|---|---|---|---|---|
| | | | Temperature. | Scale-divisions. |
| | ° | *d.* | ° | *d.* |
| 1 and 7 | 43.4 | 27.64 | 22.2 | 0.51 |
| 2 and 6 | 57.3 | 27.97 | 8.3 | 0.18 |
| 3 and 5 | 73.7 | 28.37 | 8.1 | 0.22 |
| 4.... | 87.9 | 28.61 | 22.3 | 0.46 |
| Mean. | 65.6 | 28.15 | Sum, 60.9 | 1.37 |

| | |
|---|---|
| Log $a$ | 0. 447 |
| Co. log rad. in minutes, | 6. 464 |
| Log $n$ | 0. 137 |
| Log cot $u$ | 1. 004 |
| Co. log $(t-t_0)$ | 8. 215 |
| Log $q$ | 6. 267 |

$$q = 0.000185$$

If it is desirable to check the result by the above method, we can also find the value of $q$ from three or more consecutive series of oscillations (always combined in accordance with the principle of eliminating changes in intensity) at different temperatures. Let T and $T_0$ be the observed times of one oscillation (corrected for rate of chronometer) at the temperatures $t$ and $t_0$, then

$$q = \frac{T^2 - T_0^2}{T_0^2\,(t - t_0)}$$

The various values of $q$ found from testing a large number of magnets at the Kew Observatory, were included between the limits .00076 and .00004 The value given in the text is about an average one. The coefficient depends mainly on the hardness of the steel. [See Proc. Roy. Soc. No. 181, May, 1877.]

If the magnetic moment $m$ of the magnet has been determined at a number of stations, the different values may be reduced to a standard temperature. Let $m_0$ = magnetic moment at the standard temperature $t_0$; $m$ = the magnetic moment at any other temperature $t$, then

$$m_0 = m\,[1 + (t - t_0)\,q]$$

If the values of $m_0$ are arranged according to time, the gradual loss of magnetism will become apparent in a few weeks, unless the magnet be an old one, when yearly determinations of $m$ will indicate but a slight loss. A new magnet is not well suited for intensity-determinations until after the lapse of two or three months.

22. *Introduction of absolute for relative values of the horizontal force as determined by oscillations alone.*—For this purpose we require oscillations at a base station, usually a permanent magnetic observatory, where the value of H in absolute measure is known or has been determined by means of the magnetometer. These oscillations should be taken just before setting out and again immediately after the return from a magnetic survey, in order that a proper allowance be made for loss of magnetism of the oscillating magnet during the interval.

Let H and T be the horizontal force in absolute measure and the observed time, in seconds, of an oscillation respectively, at the base station; $H_1$ and $T_1$ similar quantities at any other station, then

$$H_1 = \frac{T^2}{T_1^{\,2}} H$$

and it should be observed that all oscillations are supposed referred to a standard temperature, say 59° Fah., or 15° C. The values of $T^2H$ for the first ($e_1$) and second ($e_2$) epochs are known and their mean is taken to answer for the middle time $e_0 = \frac{1}{2}(e_1 + e_2)$, also their difference $\triangle$, which, divided by the difference $e_2 - e_1$, expressed, say, in days, gives the effect of the daily loss of magnetism of the magnet. For any time, $e$ we can easily find by interpolation the proper value of $T^2H$ by applying the effect for the interval $e - e_0$ as shown in the following example.

To reduce observations of oscillations made at any temperature, $t$ to the adopted standard temperature $t_0$ we have for the corrected value of $T^2$

$$(1 - (t - t_0)\,q)\ T^2$$

where $q$=change in magnetic moment of magnet for a change in temperature of 1° Fah. (or C.).

Suppose, for example, that August 11, 1871, the logarithm of $T^2$ was found to equal 1.18018 at the temperature of 65° Fah., and that the adopted normal temperature is 60° Fah. and the value of $q$=.00031, then $1 - (t - t_0)q = 0.99845$ and its logarithm 9.99933, which added to log $T^2$ gives the corrected value of log $T^2$=1.17951

**Example:**

| For the base station. | Log $T^2$ at $t_0$. | Log H (given). | Log $T^2$ H. | $T^2$ H. |
|---|---|---|---|---|
| $e_1$ = 1871, August 11... | 1.17951 | 0.63909 | 1.81860 | 65.857 |
| $e_0$ = 1872, June 2...... | .......... | .......... | ..... .... | 66.362 |
| $e_2$ = 1873, March 25 ... | 1.18652 | 0.63869 | 1.82521 | 66.867 |

The difference in log H for $e_1$ and $e_2$ is due to effect of secular change. We have $e_2 - e_1 = 592$ days and $\triangle = 1.010$, hence change of $T^2H$ for loss of magnetism in one day$= \frac{1.010}{592} = .00171$ and finally, from interpolation for any time $e$ the value of $T^2H$, equal to $66.362 + .00171\,(e - e_0)$.

23. *Concluding remarks.*—The degree of accuracy attainable in the magnetic measures can only be estimated; it will depend not only on the construction of the instruments used, but greatly on the time spent on the measures, chiefly on account of the almost incessant changes in the action of terrestrial magnetism. With well-constructed instruments, such as have been supposed in this

article, and with fair observations, the resulting declination for any one day may, in our magnetic latitudes, be affected with no greater probable uncertainty than about ± 1′ to ± 2′, and correspondingly less for the resulting value at a station if the observations extend over more than one day. The dip may be affected with a probable uncertainty between ± 1′ and ± 5′, according to the perfection of the needles and the number of observations made; and the horizontal intensity, in general, may become known within about its $\frac{1}{500}$ part from any one day's observations. To find the effect on the total force, we have the relation

$$d\,\mathrm{F} = d\,\mathrm{H} \sec \theta + \mathrm{F} \tan \theta \, d\,\theta$$

To secure uniformity and completeness of record the Coast-Survey observers are furnished with blank forms, Nos. 1 to 5 covering the principal operations mentioned in this paper.

If $\mathrm{F}$=total magnetic force; $\mathrm{H}$=its horizontal component; $\mathrm{V}$=its vertical component and $\theta$= the angle of the dip (reckoned from a horizontal plane), then

$$\mathrm{F} = \mathrm{H} \sec \theta = \mathrm{V} \operatorname{cosec} \theta$$

To convert measures of intensity expressed in British units into their equivalents expressed in the metric system as adopted by Gauss, in which the millimetre = 0.003280087 foot and the milligram = 0.0154323 grain are adopted, we multiply by the factor 0.46108 (log factor = 9.66378). Its reciprocal is 2.1688 (log reciprocal factor = 0.33622), by which intensity-measures expressed in metric units are to be multiplied to give their equivalents according to the British weights and measures. For the conversion of measures of intensity expressed in British units into their equivalents in the C. G. S. system, we have the log factor 8.66378 and conversely for turning measures of the C. G. S. system into their equivalents of British units the log factor 1.33622

For further information on the subject of this paper, the reader may consult, among others, the following works:

Magnetical Instructions for the use of portable instruments, &c., &c., by Lieut. C. J. B. Riddell, R. A., F. R. S., London, 1844; with supplement, London, 1846.

Handbuch des Erdmagnetismus, Dr. J. Lamont. Berlin, 1849.

Manual of Terrestrial Magnetism, by Major-General Sir E. Sabine. Extracted from the Admiralty's Manual of Scientific Enquiry, third edition, 1859.

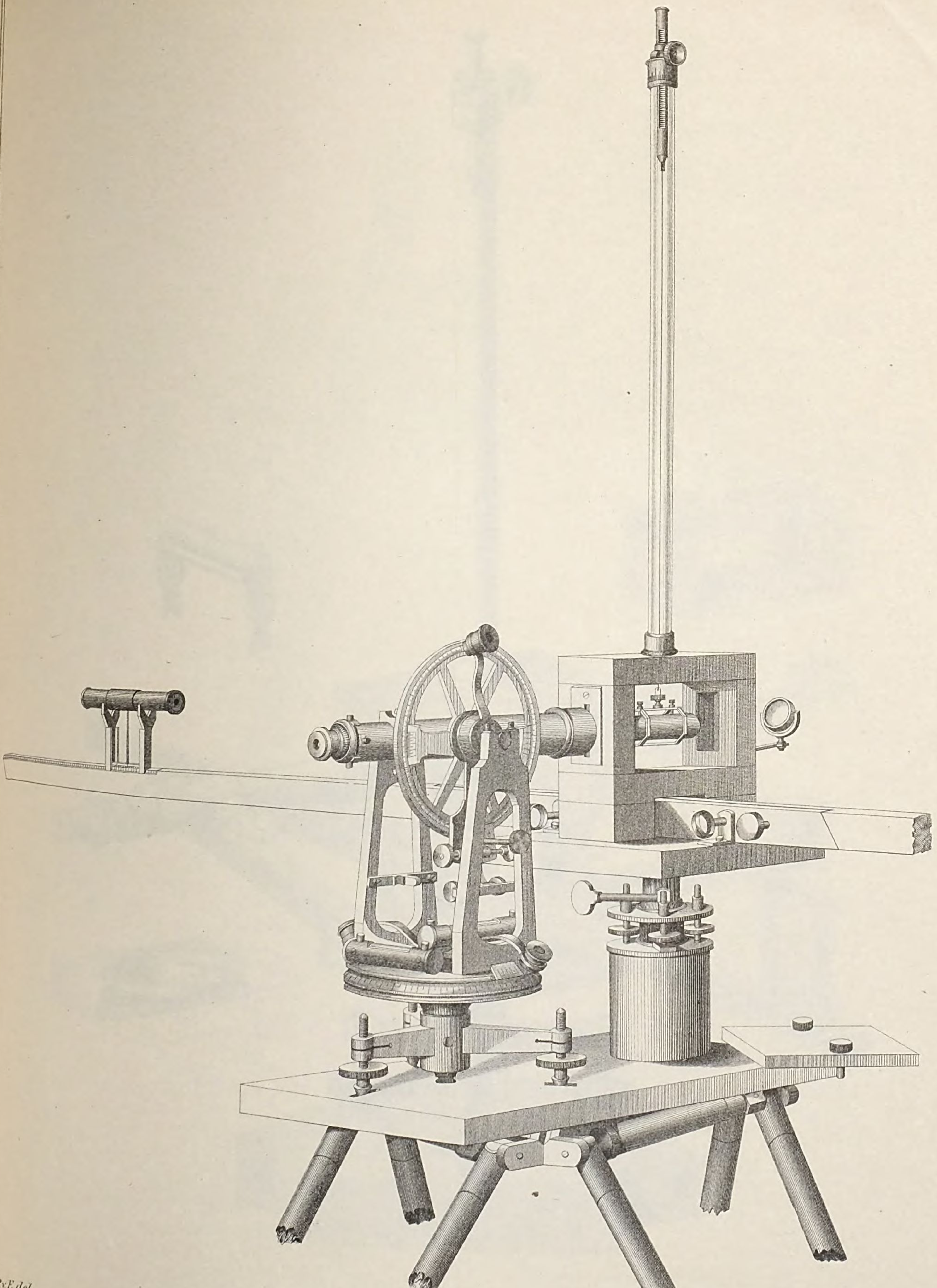
Terrestrial and Cosmical Magnetism. The Adams Prize Essay for 1865, by E. Walker, M. A. Cambridge (England), 1866.

A treatise on magnetism, by Sir G. B. Airy. London, 1870.

A treatise on magnetism, general and terrestrial, by H. Lloyd, D. D., D. C. L. London, 1874.

Units and Physical Constants, by Prof. J. D. Everett. London, 1879.

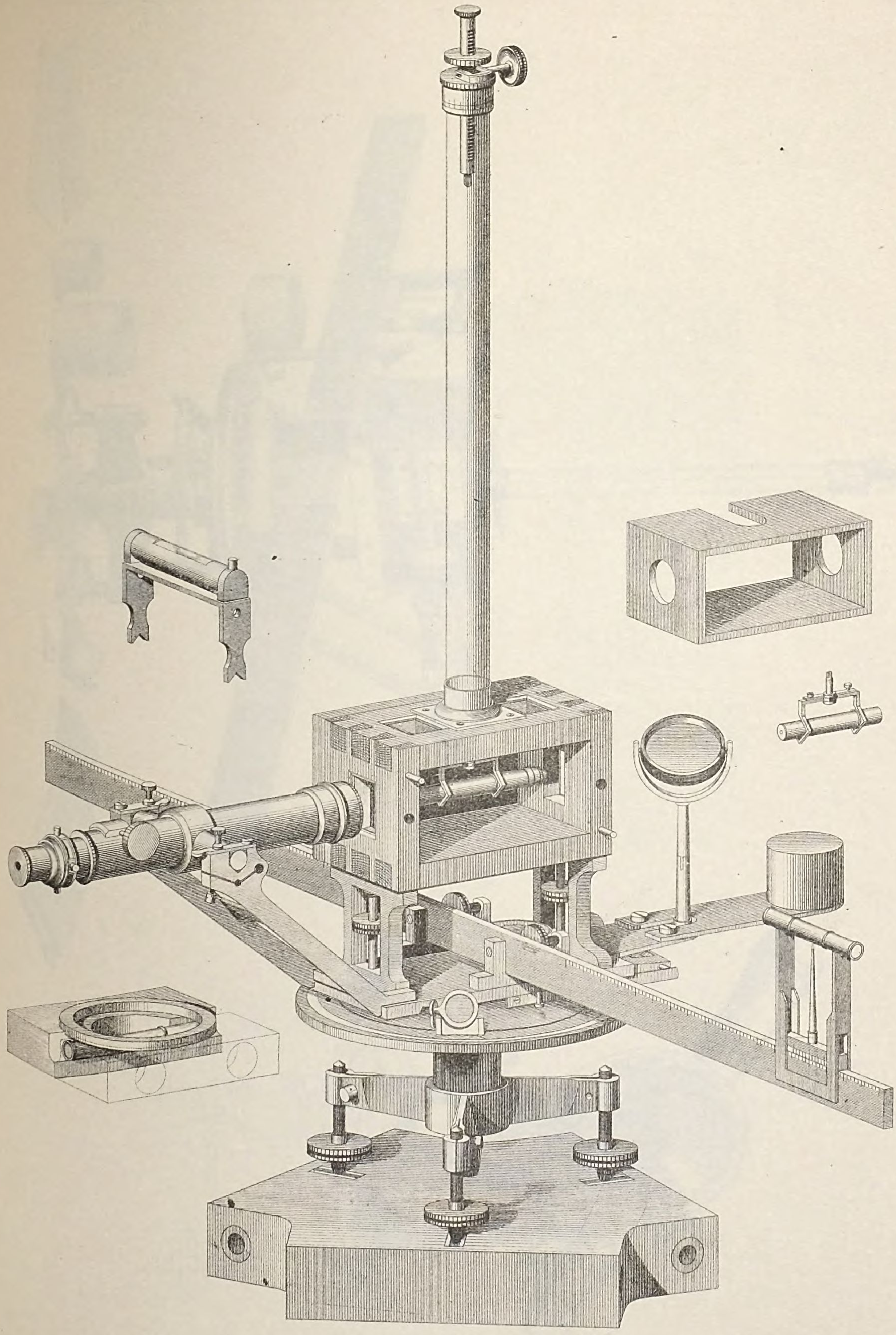
A physical treatise on electricity and magnetism, by J. E. H. Gordon; in 2 vols. New York, 1880.



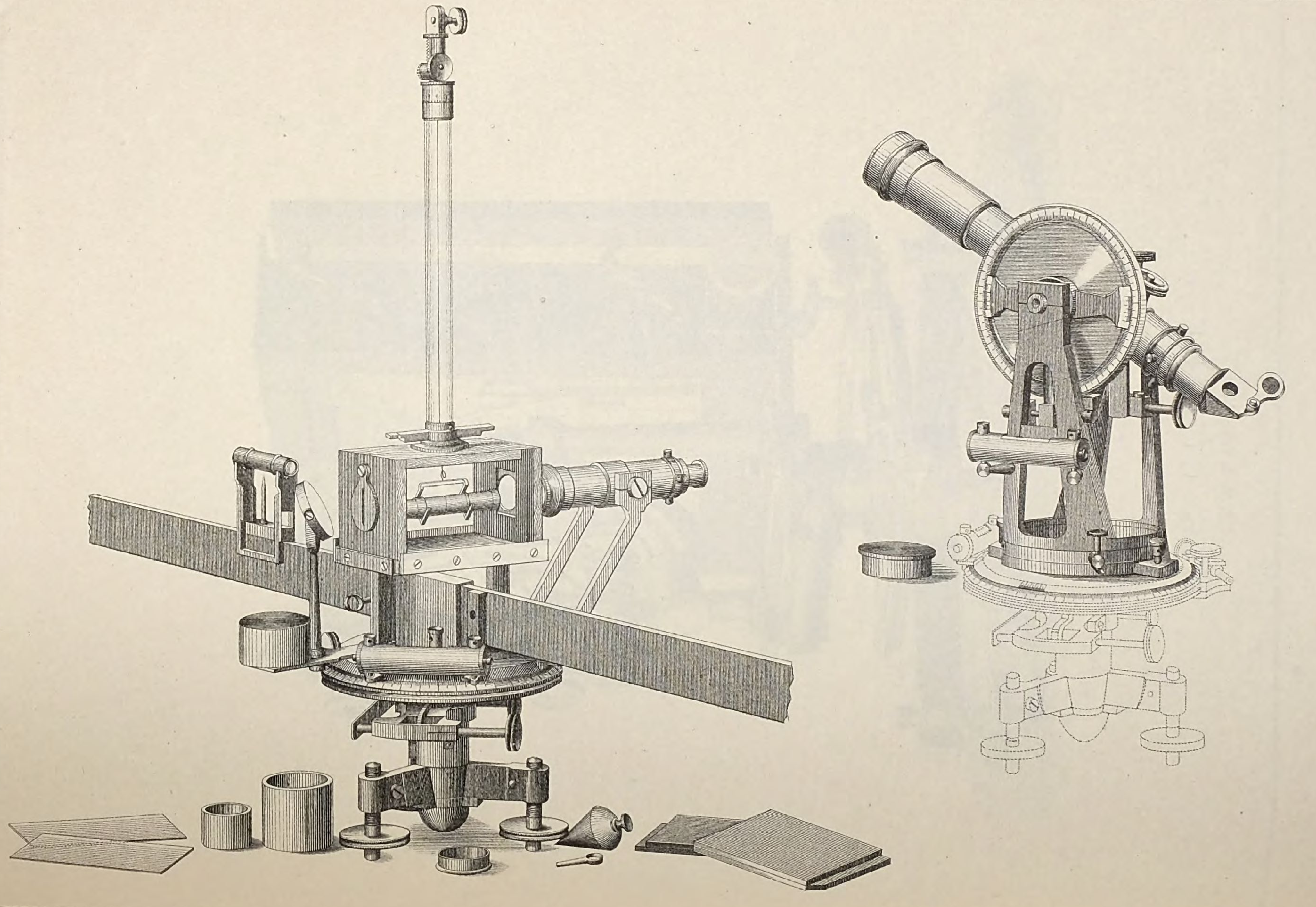
P.v.E. del.

MAGNETOMETER

( WITH THEODOLITE, WEBER'S DESIGN )

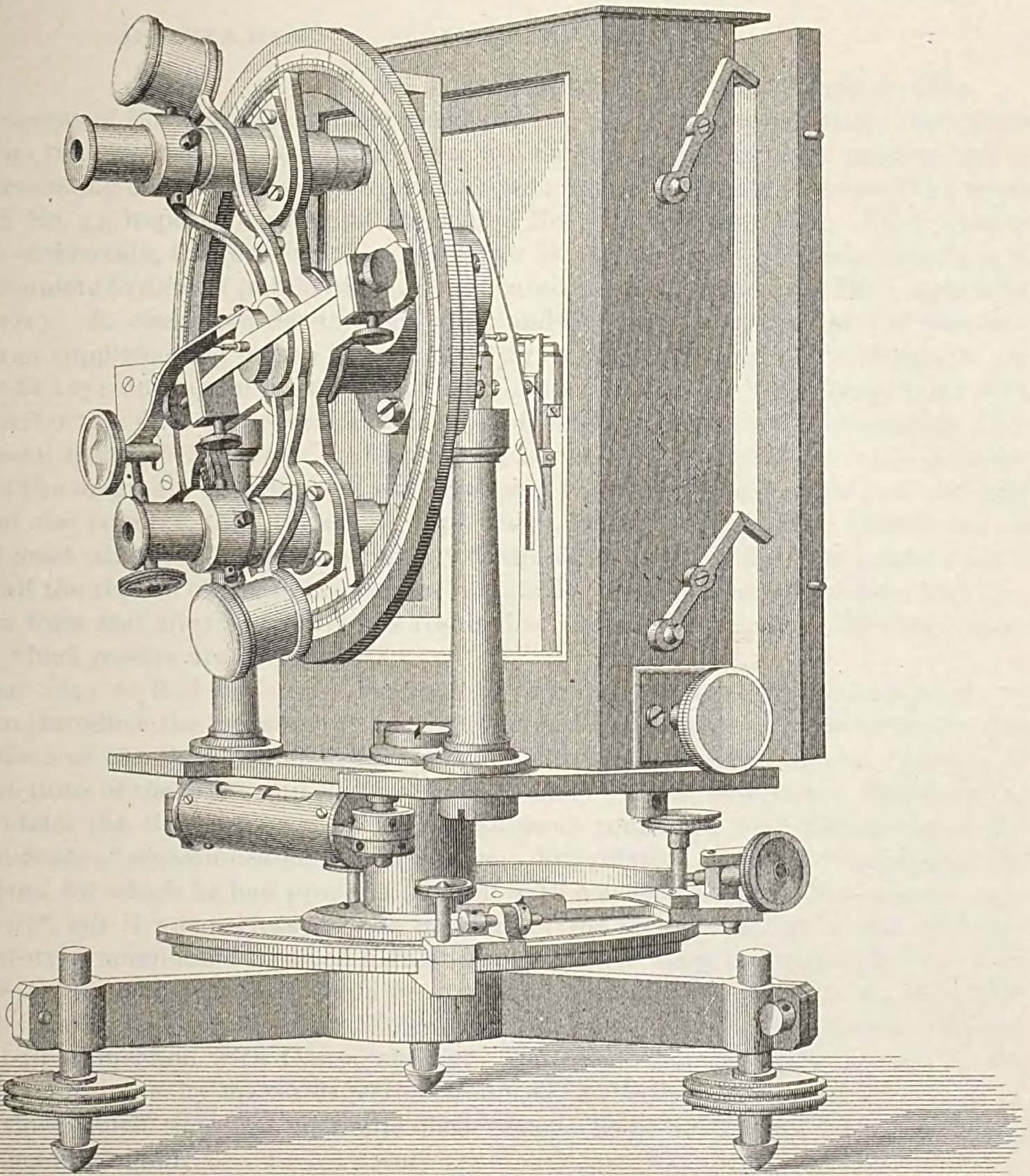


MAGNETOMETER
(LAMONT'S DESIGN)



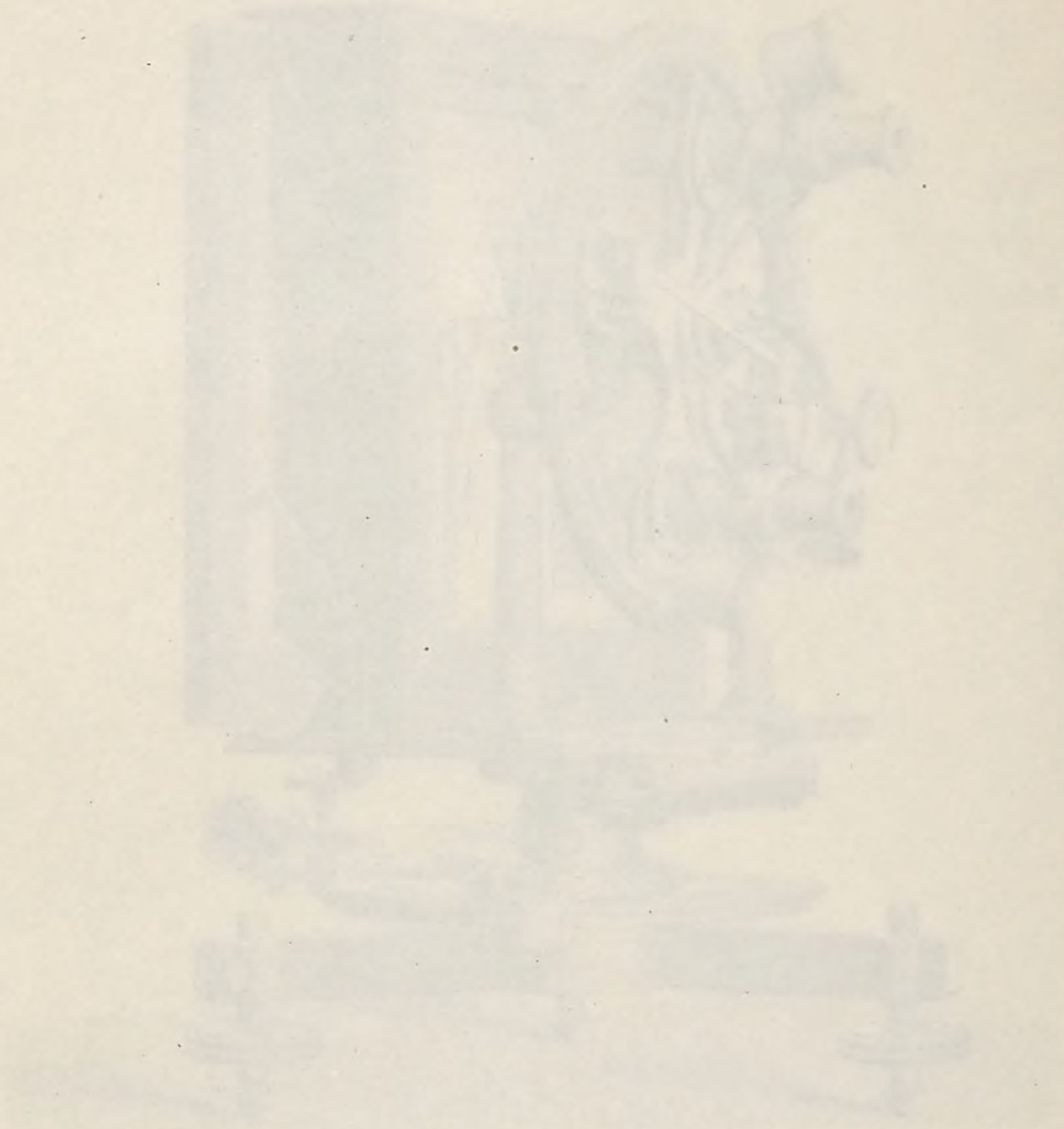
ALT-AZIMUTH AND MAGNETOMETER

(U.S. COAST SURVEY.)



DIP CIRCLE

(KEW PATTERN).



# APPENDIX No. 9.

## TERRESTRIAL MAGNETISM—COLLECTION OF RESULTS FOR DECLINATION, DIP AND INTENSITY, FROM OBSERVATIONS MADE BY THE UNITED STATES COAST AND GEODETIC SURVEY BETWEEN 1833 AND 1882, JULY.

By CHARLES A. SCHOTT, Assistant.

COMPUTING DIVISION, *June* 30, 1882.

During the progress of the operations of the Survey from 1844 to the present time, there have been presented from time to time in the annual reports a number of fragmentary publications of magnetic results depending on the observations accumulated; principal among these are the papers given in Appendix No. 43, Report for 1854, and Appendix No. 47, Report for 1855. They contain declination results exclusively, the former at 136, the latter at 153 stations. The only collection of magnetic results complete to date of publication is that contained in the Report for 1856, Appendix No. 28 (pp. 215–221). It comprises declinations, dips and intensity measures at 157 stations. This publication was supplemented in the Report for 1858, Appendix No. 24, which brings up the number of stations to 185; and again in Report for 1860, Appendix No. 28, which terminates with Station No. 204. After this date no general publication of magnetic results was attempted, only some partial or special results being given. After so long an interval, and with the rapid development and spread of the magnetic operations of the Coast and Geodetic Survey since 1878 into and over the interior of the country, thus filling up gaps which, for the study of the distribution of magnetism needed most attention, it appeared highly desirable to bring before the public a complete collection of all the results of the Survey so far obtained. This has now been done in a systematic and concise form and after the individual results had undergone revision. The total number of stations for which results are given is 638.

Before the year 1844 we find but a few declinations recorded, though Superintendent F. R. Hassler intended to introduce the measure of the magnetic declination and relative intensity into the regular operations of the Survey and describes and figures his azimuth-compass (pattern of 1801) in the Transactions of the American Philosophical Society (vol. ii, new series, Philadelphia, 1825, pp. 354–356) under the title, "Papers on various subjects connected with the survey of the coast of the United States," communicated March 3, 1820. For relative intensity he proposed the method of oscillations, for which he had provided himself with a special needle. This was the only method then known;* but it was useless for the measure of the secular change of the intensity. The interest in terrestrial magnetism received a great impetus after Gauss had shown, in 1833, how the intensity of the earth's magnetic force could be expressed in absolute measure; and the observations for intensity multiplied greatly after Weber, in 1836, had produced the portable magnetometer, to be used in connection with Gauss' theory. The magnetometer came into use in the Survey in 1844; dip† and intensity measures were introduced in the Survey by Superintendent A. D. Bache in 1844, since which time the magnetic observations have made steady progress. All observations were made on land.

Respecting the construction and use of the magnetic instruments, the reader may be referred to preceding Appendix (No. 8), entitled, "Directions for Measurement of Terrestrial Magnetism,"

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*The first observations showing a *difference* of intensity of the earth's magnetic total force, as shown by oscillations of the dipping-needle in the plane of the magnetic meridian, appear to have been made by Lamanon between 1785 and 1787. These were followed up by de Rossel (1791–'94), and A. v. Humboldt (1798–1803). This coarse method was changed into another, admitting of great accuracy, by Hansteen, who substituted the horizontal for the vertical needle, and suspending it by a silk fiber, measured relative horizontal force; he was followed by Duperrey (1822–'25) and others. The method, supplemented by absolute measure at the base station, is frequently used in the Coast and Geodetic Survey.

†All the earlier dip-circles had their needles mounted in the plane of the circle; the later and improved instruments have graduated circles in front of the needle, read by means of microscopes.

third edition, with four plates. For each of the magnetometers there is on file in the archives of the Survey a description and a collection of the several constants appertaining to the instrument, but it has been thought unnecessary to reproduce this information in connection with this paper.

## EXPLANATION OF THE TABLES OF MAGNETIC RESULTS.

The tables are arranged by States and Territories in alphabetical order and end with a table headed "Foreign countries." For each State or Territory the results are given in chronological order, divided into sixteen columns, containing the following information:

Column 1 gives the running number of stations, not counted again when reoccupied; a blank space in this column therefore indicates that the station has been occupied before, either once or several times.

Column 2 contains the name of the station or of the locality.

Columns 3 and 4 contain the geographical latitude and longitude of the station, according to the best information at present available.

Columns 5 and 6 give the date, year, month and day of the observations for declination.

Column 7 contains the resulting magnetic declination, + when the north-seeking end of the magnet (or its marked end) is *west* of the true meridian and — when *east* of it.

Column 8 gives the date (year as in column 5), month and day of the observations for dip.

Column 9 contains the resulting magnetic dip, + when the north-seeking end is *depressed* below the horizon and — when *elevated* above it.

Column 10 gives the date (year as in column 5), month and day of the observations for horizontal component and for total magnetic force.

Columns 11 and 12 contain the resulting numerical value, in absolute measure, of the horizontal component of the earth's magnetic intensity, the first in British units (viz, the foot, the grain, and the second of mean time); the second, the British Association or C. G. S. units (viz, the centimetre, the gramme and the second of mean time).* From the latter system we obtain, also, by simple inspection, the magnetic intensity expressed in the metric units adopted by Gauss (viz, the millimetre, the milligramme and the second of mean time) by simply shifting the decimal point one place to the right.†

Columns 13 and 14 contain the resulting numerical value of the earth's total magnetic intensity; the first expressed in the usual British units, the second in C. G. S. units or dynes. The tabular quantity given for any place is the force (in dynes, for the C. G. S. system) which a magnetic pole of unit strength will experience when put in the magnetic field at that place.

Column 15 gives the observer's name.

Column 16 the instrument employed, M. standing for magnetometer; Th. M. for theodolite magnetometer; D. C. for dip-circle, with their respective numbers attached.

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* The multiplier required for changing values of magnetic intensity from the foot-grain-second system to the C. G. S. system is found directly from the dimensional equation for the unit of field-intensity, $M^{\frac{1}{2}} L^{-\frac{1}{2}} T^{-1}$. Taking a grain equal $.064799^{gm}$ and a foot equal $30.4797^{cm}$, this factor becomes $\sqrt{\frac{.064799}{30.4797}} = .046108$; and its logarithm, 8.66378

† To find the multiplier required for changing values of magnetic intensity from the C. G. S. system to the Gaussian or mm-mg-s system, we have $1^{cm} = 10^{mm}$ and $1^{gm} = 1000^{mg}$; hence the factor $\frac{1}{T}\sqrt{\frac{M}{L}} = 10$

# TABLES OF MAGNETIC RESULTS.

## ALABAMA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Fort Morgan. | 30 13.9 | 88 01.2 | 1847 | May 21, 22, 23, 28, 29, 30. | − 7 04.1 | ............ | ...... | May 19, 20, 29. | 6.218 | .2867 | .... | .... | R. H. Fauntleroy, J. S. Ruth. | M. 2. |
| 2 | Montgomery. | 32 22.8 | 86 18.0 | 1856 | Apr. 2, 3, 4, 5. | − 5 18.3 | Apr. 3, 4. | 63 05.4 | Apr. 7, 8. | 5.859 | .2701 | 12.946 | .5969 | G. W. Dean. | M. 1, D. C. 4. |
| 3 | Mobile. | 30 41.6 | 88 02.6 | 1857 | Feb. 14, 16, 17, 18 | − 6 52.2 | Feb. 9, 10. | 60 51.0 | Feb. 20, 21, 25. | 6.150 | .2836 | 12.625 | .5821 | E. Goodfellow. | do. |
| 4 | Lower Peach Tree. | 31 50.4 | 87 32.7 | 1857 | Apr. 30, May 1, 2 | − 6 02.4 | Apr. 3, May 2. | 62 16.8 | May 4, 5. | 5.975 | .2755 | 12.846 | .5923 | G. W. Dean. | do. |
| 5 | Eufaula. | 31 53.7 | 85 08.4 | 1860 | Apr. 10, 12. | − 5 12.1 | Apr. 10, 11. | 63 05.8 | Apr. 13, 14. | 5.739 | .2646 | 12.684 | .5848 | do. | do. |
| 6 | Florence. | 34 47.2 | 87 41.7 | 1865 | Apr. 17. | − 5 24 | ............ | ...... | ............ | .... | .... | .... | .... | A. T. Mosman. | Azim. compass. |
| 7 | Indian Mt. | 34 01.8 | 85 25.6 | 1875 | Aug. 23, 24, 25. | − 4 10.6 | Aug. 23, 24, 25. | 65 09.5 | Aug. 23, 24, 25. | 5.472 | .2523 | 13.025 | .6006 | F. P. Webber. | M. 3, D. C. 8. |
| 8 | Decatur. | 34 37 | 86 59 | 1881 | Aug. 27, 29. | − 5 10.3 | Aug. 27, 29. | 65 35.2 | Aug. 26, 27. | 5.312 | .2449 | 12.852 | .5926 | J. B. Baylor. | M. 9, D. C. 18. |
| | Florence. | 34 47.0 | 87 43 | 1881 | Sept. 5, 6. | − 4 37.8 | Sept. 5, 6. | 65 52.1 | Sept. 5, 6. | 5.297 | .2442 | 12.956 | .5974 | do. | do. |

## ALASKA TERRITORY.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sitka. | 57 02.9 | 135 20.1 | 1867 | Aug. 17, 18, 19, 20. | −28 49 | ............ | ...... | ............ | .... | .... | .... | ... | A. T. Mosman. | Th. M. III. |
| 2 | Kadiak, harbor of Saint Paul. | 57 48.0 | 152 21.4 | 1867 | Aug. 28, 29. | −26 04.7 | ............ | ...... | ............ | .... | ... | .... | .... | do. | do. |
| 3 | Unalashka, Captain's Harbor. | 53 53.9 | 166 30.4 | 1867 | Sept. 8, 9. | −19 47.4 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 4 | Kohklux. | 59 23.7 | 135 53.5 | 1869 | July 30, 31, Aug. 1 | ...... | July 31. | 75 44 | Aug. 2, 3. | 3.297 | .1520 | 13.38 | .6168 | G. Davidson. | Th. M. III, D. C. 5. |
| | Unalashka, Iliuliuk Harbor. | 53 52.9 | 166 31.7 | 1871 | Nov. 11. | −18 36 | ............ | ...... | ............ | ... | .... | .... | .... | W. H. Dall. | Small Casella Th. |
| 5 | Chichagoff Harbor, Attu Island | 52 56.0 | −173 12.4 | 1873 | June 25, 26. | − 7 43.0 | June 26. | 65 10.6 | ............ | .... | .... | .... | .... | do. | 5-inch comp. N., D.C.1. |
| 6 | Kyska Harbor, Kyska Island. | 51 59.1 | −177 30.0 | 1873 | July 18, 22. | −11 06.4 | July 22. | 65 01.3 | ............ | .... | .... | .... | .... | do. | do. |
| 7 | Amchitka Island, Constantine Harbor. | 51 23.7 | −179 12.1 | 1873 | July 29. | − 7 17.1 | ............ | ...... | ............ | .... | .... | .... | .... | do. | 5-inch comp. N. |
| 8 | Adakh Island, Bay of Seven Islands. | 51 49.3 | 176 52.0 | 1873 | Aug. 11. | −13 52.1 | ............ | ..... | ............ | .... | .... | .... | .... | do. | do. |
| 9 | Atka Island, Nazan Bay. | 52 10.6 | 174 15.3 | 1873 | Aug. 24. | −16 57.3 | ............ | ...... | ............ | .... | .... | ... | .... | do. | do. |
| | Unalashka. | 53 52.9 | 166 31.7 | 1873 | May 26, 27, Sept. 18, 19. | −19 03.2 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall, M. Baker | do. |
| 10 | Popoff Strait, Humboldt Harbor, Shumagin Islands. | 55 19.3 | 160 31.2 | 1873 | Oct. 7, 10, 17. | −20 28.9 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall. | do. |
| | Sitka. | 57 02.9 | 135 19.7 | 1874 | May 4, 5. | −28 59.5 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall, M. Baker | do. |
| 11 | Lituya Bay. | 58 37.0 | 137 40.1 | 1874 | May 16. | −30 02.8 | ............ | ...... | ............ | .... | ... | .... | ... | W. H. Dall. | do. |
| 12 | Port Mulgrave. | 59 33.7 | 139 46.3 | 1874 | May 22. | −29 58.3 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall, M. Baker | do. |
| 13 | Port Etches. | 60 20.7 | 146 37.6 | 1874 | May 31. | −29 09.8 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall. | do. |
| | Kadiak Island. | 57 48.0 | 152 21.4 | 1874 | June 7. | −25 22.0 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall, M. Baker | do. |
| 14 | Chirikoff Island. | 55 48.4 | 155 42.8 | 1874 | June 11. | −23 00.9 | ............ | ...... | ............ | .... | .... | .... | .... | W. H. Dall. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### ALASKA TERRITORY—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
| 15 | Semidi Islands. | 56 05.2 | 156 39.3 | 1874 | June 13. | −22 56.9 | ........... | ...... | ........... | .... | .... | .... | .... | W. H. Dall. | 5-inch comp. N. |
| 16 | Chiachi Islands. | 55 52.0 | 159 05.4 | 1874 | June 26. | −21 55.9 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 17 | Chignik Bay. | 56 19.3 | 158 24.4 | 1874 | June 19. | −22 01.7 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 18 | Little Koniushi, N.W. Harbor, Shumagin Islands. | 55 03.3 | 159 23.3 | 1874 | July 5. | −21 45.8 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 19 | Saint Paul Island, Pribiloffs. | 57 07.3 | 170 17.9 | 1874 | July 24. | −17 18.9 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 20 | Nunivak Islands, north end Cape Etonin. | 60 25.4 | 166 08.5 | 1874 | July 31. | −21 33.8 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 21 | Hagmeister Island. | 58 48.5 | 160 50.0 | 1874 | Aug. 7. | −22 52.8 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 22 | Port Moeller. | 55 55.0 | 160 34.9 | 1874 | Aug. 12. | −21 22.2 | ........... | ...... | ........... | .... | ... | .... | .... | do. | do. |
|  | Unalashka. | 53 52.9 | 166 31.7 | 1874 | Sept. 15. | −18 42.8 | ........... | ...... | ........... | .... | .... | .... | .... | W. H. Dall, M. Baker | do. |
| 23 | Kasaan Bay, Prince of Wales Archipelago, Clarence Strait. | 55 29.5 | 132 19 | 1880 | May 9. | −27 48 | May 9. | 73 58 | ........... | .... | .... | .... | .... | do. | D. C. 21, Mag'c. Th. 123. |
| 24 | Fort Wrangell, Etolin Island. | 56 30.5 | 132 23 | 1880 | ............. | ...... | May 10. | 75 19.2 | ........... | .... | .... | .... | .... | do. | D. C. 21. |
| 25 | Poverotni Station, Peril Strait. | 57 28.4 | 135 27.5 | 1880 | ............. | ...... | May 20. | 75 03.4 | ........... | ... | .... | .... | .... | do. | do. |
| 26 | Marble Bluff, Chatham Strait. | 57 45 | 134 43.5 | 1880 | ............. | ...... | May 22. | 75 57.3 | ........... | .... | .... | ... | .... | do. | do. |
| 27 | Near Point Marsden, Admiralty Island. | 58 05 | 134 49 | 1880 | ............. | ...... | May 23. | 76 02.1 | May 23. | 3.124 | .1440 | 12.94 | .5968 | do. | do. |
| 28 | Point Whidbey, Lynn Canal. | 58 36.5 | 135 15 | 1880 | ............. | ...... | May 24. | 76 27.3 | ........... | .... | .... | .... | .... | do. | do. |
| 29 | Pyramid Island Harbor, Lynn Canal. | 59 10.6 | 135 28.5 | 1880 | ............. | ...... | May 25, 26. | 75 34.7 | May 25, 26. | 3.277 | .1511 | 13.15 | .6067 | do. | do. |
| 30 | Seduction Island, Lynn Canal. | 58 59.5 | 135 22 | 1880 | ............. | ..... | May 29. | 76 44.3 | ........... | .... | .... | .... | .... | do. | do. |
| 31 | Hot Springs Bay, Sitka Sound. | 56 51.7 | 135 20.3 | 1880 | ............. | ..... | June 9. | 75 01.9 | June 9. | 3.345 | .1542 | 12.95 | .5970 | do. | do. |
|  | Sitka. | 57 02.9 | 135 20.3 | 1880 | May 17, 18. | −29 04.8 | May 17, 18. | 75 11.7 | May 17, 18. | 3.310 | .1526 | 12.95 | .5972 | do. | D. C. 21, Mag'c. Th. 123. |
| 32 | Port Althorp, Cross Sound. | 58 11.5 | 136 23.5 | 1880 | June 19. | −32 15.5 | June 19. | 75 22.3 | June 19. | 3.279 | .1512 | 12.98 | .5987 | do. | do. |
|  | Port Mulgrave. | 59 33.7 | 139 45.9 | 1880 | June 24. | −29 59.8 | June 24. | 76 17.9 | June 24. | 3.067 | .1414 | 12.95 | .5970 | do. | do. |
| 33 | Coal (Ugolnvi) Point, Chugachik Gulf, Cook's Inlet. | 59 36.1 | 151 23.6 | 1880 | June 30. | −25 48.5 | June 30. | 73 59.6 | June 30. | 3.464 | .1597 | 12.56 | .5791 | do. | do. |
| 34 | Dangerous Cape, Cook's Inlet. | 59 23.9 | 151 53 | 1880 | July 4. | −24 32.5 | ........... | ...... | ........... | .... | .... | .... | .... | do. | Mag'c. Th. 123. |
|  | Saint Paul, Kadiak Island. | 57 48.0 | 152 21.3 | 1880 | July 9. | −25 09.2 | July 12. | 72 34.6 | July 12. | 3.721 | .1716 | 12.43 | .5731 | do. | D. C. 21, Mag'c. Th. 123. |
|  | N.W. Harbor, Little Koniushi, Shumagin Islands. | 55 03.3 | 159 23.5 | 1880 | July 16. | −21 25.2 | July 16. | 69 30.3 | July 16. | 4.198 | .1936 | 11.99 | .5529 | do. | do. |
|  | Humboldt Harbor, Popoff Island, Shumagins. | 55 19.3 | 160 31.0 | 1880 | July 19. | −20 17.0 | July 19. | 69 28.8 | July 19. | 4.208 | .1940 | 12.00 | .5534 | do. | do. |
| 35 | Dolgoi Island, south end. | 55 03.3 | 161 43.3 | 1880 | July 22. | −17 59 | ........... | ...... | ........... | .... | .... | .... | .... | do. | Mag'c. Th. 123. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 36 | Belkoffsky ettlement, Dolgoi Island. | 55 05.2 | 162 00.2 | 1880 | July 23. | −21 25.7 | July 23. | 69 16.2 | July 23. | 4.193 | .1933 | 11.84 | .5461 | do. | D. C. 21, Mag'c. Th. 123. |
| | Iliuliuk Harbor, Unalashka. | 53 52.9 | 166 31.7 | 1880 | July 28, 29. | −18 38.0 | July 28, Oct. 7. | 67 35.8 | July 29, Oct. 7. | 4.456 | .2055 | 11.69 | .5392 | do. | do. |
| | Saint Paul Island, Pribiloff Islands. | 57 07.3 | 170 19.0 | 1880 | Aug. 6. | −17 39.2 | Aug. 6. | 68 36.6 | Aug. 6. | 4.356 | .2008 | 11.94 | .5506 | do. | do. |
| 37 | Near Cape Lisburne. | 68 52.9 | 166 05.5 | 1880 | Aug. 21. | −25 42.8 | Aug. 21. | 78 53.0 | Aug. 21. | 2.460 | .1134 | 12.76 | .5882 | do. | do. |
| 38 | Sandy Beach, between Point Lay and Icy Cape. | 70 13.2 | 162 15.2 | 1880 | Aug. 25. | −30 05.7 | Aug. 25. | 80 07.8 | Aug. 25. | 2.195 | .1012 | 12.81 | .5904 | do. | do. |
| 39 | Near Point Belcher. | 70 47 | 159 40 | 1880 | .............. | ...... | Aug. 27. | 80 52.6 | Aug. 27. | 2.035 | .0938 | 12.84 | .5916 | do. | D. C. 21. |
| 40 | Chamisso Harbor, Kotzebue Sound. | 66 13.3 | 161 48.7 | 1880 | Aug. 31. | −26 49 | Aug. 31. | 77 17.4 | Aug. 31. | 2.791 | .1287 | 12.68 | .5849 | do. | D. C. 21, Mag'c. Th. 123. |
| 41 | Port Clarence. | 65 16.1 | 166 50.6 | 1880 | Sept. 8. | −22 45 | Sept. 6. | 76 04.0 | Sept. 8. | 3.022 | .1393 | 12.55 | .5785 | do. | do. |
| 42 | Cove Point, Chernoffsky Bay, Unalashka Island. | 53 24.0 | 167 29.9 | 1880 | Oct. 2. | −16 15.3 | Oct. 2. | 67 13.8 | Oct. 2. | 4.544 | .2095 | 11.74 | .5413 | do. | do. |
| 43 | Shukan, Prince of Wales Islands. | 56 09.4 | 133 38.5 | 1881 | Aug. 16. | −30 03.2 | Aug. 15. | 74 49.7 | Aug. 16. | 3.395 | .1565 | 12.97 | .5980 | H. E. Nichols, Lieut. U. S. N., act. asst. C. and G. S. | Th. M. III, D. C. 10. |
| | Fort Wrangell. | 56 28.2 | 132 23 | 1881 | Aug. 19, 20, 21. | −29 17.0 | Aug. 17. | 75 32.8 | Aug. 19, 20, 21. | 3.265 | .1505 | 13.08 | .6030 | H. E. Nichols. | do. |
| 44 | Howcan Mission, Kaigani Straits. | 54 49.5 | 132 50 | 1881 | Sept. 2. | −27 03.4 | Sept. 1. | 74 21.5 | Sept. 2. | 3.805 | .1754 | 14.11 | .6506 | do. | do. |
| | Sitka. | 57 02.9 | 135 20.3 | 1881 | Sept. 15, 16. | −29 11.2 | Sept. 12, 16. | 75 16.6 | Sept. 16. | 3.293 | .1518 | 12.96 | .5973 | do. | do. |

## CALIFORNIA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Point Conception, El Coxo. | 34 27.0 | 120 26.7 | 1850 | Sept. 5, 6, 7, 8. | −13 50.2 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Th. M. III. |
| 2 | Point Pinos. | 36 37.8 | 121 55.5 | 1851 | Feb. 6, 7, 8, 9, 10. | −14 58.3 | ............ | .. | ............ | .... | .... | .... | .... | do. | do. |
| 3 | San Diego, Point Loma. | 32 42.0 | 117 14.7 | 1851 | Apr. 28 to May 7; 9 days. | −12 28.8 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 4 | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1852 | Feb., Mar., Apr., May. | −15 28.8 | Feb. 11, 12. | 62 21.2 | ............ | .... | .... | .... | .... | F. A. Roe, G. Davidson. | Th. M. III, Robinson D. C. |
| 5 | Bucksport, Humboldt Bay. | 40 46.6 | 124 11.5 | 1853 | July 19, 20. | −17 06.5 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Th. M. III. |
| | San Diego, La Playa. | 32 42.2 | 117 14.5 | 1853 | Oct. 15. | −12 31.7 | Sept. | 57 38.6 | Oct. 7, 8. | 6.271 | .2891 | 11.72 | .5402 | W. P. Trowbridge. | M. 4, Barrow D. C. |
| 6 | San Pedro. | 33 45.4 | 118 17.0 | 1853 | Nov. 24, 25, 26. | −13 30.5 | Nov. 26, Dec. 12. | 59 32.6 | Dec. 1, 2. | 6.144 | .2833 | 12.12 | .5589 | do. | do. |
| 7 | San Luis Obispo. | 35 10.6 | 120 44.5 | 1854 | Jan. 30, Feb. 6, 7. | −14 16.9 | Jan. 26, 28, Feb. 7, 8. | 59 42.2 | Feb. 6. | 6.002 | .2767 | 11.90 | .5485 | do. | do. |
| 8 | Humboldt. | 40 44.7 | 124 12.8 | 1854 | Apr. 25 to May 2; 8 days. | −17 04.5 | ............ | ...... | ............ | .... | ... | .... | .... | G. Davidson, A. Tod | Th. M. III. |
| 9 | Monterey. | 36 36.2 | 121 53.8 | 1854 | May 29, 30. | −14 58.9 | May 19, 22. | 60 59.5 | May 22, 23, 24, 25. | 5.802 | .2675 | 11.96 | .5516 | W. P. Trowbridge. | M. 4, Barrow D. C. |
| 10 | Tomales Bay. | 38 10.8 | 122 56.8 | 1857 | Feb. 4, 5, 6, 7. | −16 00.4 | ............ | ...... | .......... | .... | .... | .... | .... | G. Davidson. | Th. M. III. |
| 11 | Ross Mountain. | 38 30.2 | 123 07.2 | 1860 | Jan. 14–18. | −16 23.2 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 12 | Bodega. | 38 18.2 | 123 00.1 | 1860 | July 23–27. | −16 18.8 | ............ | ...... | Aug. 15, 16, 17. | 5.558 | .2563 | .... | .... | do. | do. |
| 13 | Santa Barbara. | 34 24.2 | 119 42.8 | 1869 | Nov. 16–19. | −15 11.9 | Nov. 20, 22, 24 | 59 16.0 | Nov. 25. | 5.967 | .2751 | 11.68 | .5383 | S. R. Throckmorton (G. Davidson). | Th. M. 5, D. C. 11. |
| 14 | San Buenaventura. | 34 15.8 | 119 15.9 | 1870 | Jan. 15–19. | −15 08.0 | Jan. 13, 14. | 59 11.5 | Jan. 19. | 6.018 | .2775 | 11.75 | .5418 | do. | Th. M. 5. |
| 15 | Dominguez Hill. | 33 51.8 | 118 14.2 | 1870 | Feb. 28–Mar. 14. | −15 20.8 | Mar. 17, 18. | 58 49.2 | Mar. 17. | 6.056 | .2792 | 11.70 | .5393 | do. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### CALIFORNIA—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
| 15 | Punta Arena. | 38 55.2 | 123 44.0 | 1870 | May 27–30. | −17 38 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Th. M. 5. |
| 17 | San Diego. | 32 43.1 | 117 09.7 | 1871 | May 28, 29, 30. | −14 46.7 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 18 | Eureka. | 40 48.1 | 124 09.6 | 1871 | July 29. | −18 42.4 | ............ | ...... | ............ | ... | .... | .... | .... | do. | do. |
|  | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1871 | Dec. 14, 15, 16. | −16 23.1 | ............ | ...... | ............ | .... | .... | .... | .... | S. R. Throckmorton (G. Davidson). | do. |
|  | do. | 37 47.5 | 122 27.2 | 1872 | Oct. 26, 27, 28. | −16 25.7 | ............ | .. .. | ............ | .... | .... | .... | .... | do. | Th. M. III. |
|  | San Diego, La Playa. | 32 42.2 | 117 14.6 | 1872 | Nov. 19, 20, 21. | −13 19.4 | Nov. 23. | 57 56.8 | Nov. 22, 23. | 6.159 | .2840 | 11.60 | .5351 | S. R. Throckmorton. | Th. M. III, D. C. 12. |
|  | Point Conception, El Coxo. | 34 27.0 | 120 26.7 | 1872 | Dec. 6, 7, 8. | −14 51.8 | Dec. 11. | 58 51.0 | Dec. 9, 10. | 5.905 | .2723 | 11.41 | .5264 | do. | do. |
|  | Point Pinos. | 36 37.8 | 121 55.6 | 1873 | Aug. 30, 31, Sept. 1. | −15 55.3 | Sept. 1. | 61 12.5 | Sept. 2. | 5.696 | .2626 | 11.83 | .5452 | do. | do. |
|  | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1873 | June, Aug., Nov.; 13 days. | −16 24.8 | Nov. 13, 15, 16, 17, 18, 20. | 62 05.1 | Nov. 17, 18, 19 | 5.543 | .2556 | 11.84 | .5460 | G. Davidson, S. R. Throckmorton, W. Eimbeck, T. J. Lowry. | do. |
|  | do. | 37 47.5 | 122 27.2 | 1874 | Jan. 10, 12, 13. 14, Feb. 19, 20, 21. | −16 26.9 | ....... .... | ...... | ....... .... | .... | .... | .... | .... | W. Eimbeck. | Th. M. III. |
|  | do. | 37 47.5 | 122 27.2 | 1879 | Mar. 12, 13, 14, 15 | −16 34.0 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson, B. A. Colonna. | do. |
| 19 | Lake Tahoe, southern shore. | 38 55 | 120 05 | 1879 | Sept. 18. | −16 48 | ....... .... | ...... | ............ | ... | .... | .... | .... | E. Hergesheimer. | Surveyor's compass. |
| 20 | Table Mountain. | 37 55 | 122 36 | 1879 | Nov. 5. | −16 00 | ............ | ...... | ............ | .... | .... | .... | . .. | do. | do. |
|  | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1880 | ............. | ...... | Apr. 12, 16, 17, 21, 22. | 62 16.7 | Apr. 16, 17, 21, 22.<br>Nov. 16, 17, 18, 19. | 5.526 | .2548 | 11.89 | .5484 | W. H. Dall, M. Baker | Magc. Th. 123, D. C. 21. |
|  |  |  |  | 1880 | Nov. 20. | −16 39.5 | Nov. 16, 17, 18, 19. | 62 20.9 |  |  |  |  |  |  |  |
|  | do. | 37 47.5 | 122 27.2 | 1880 | Sept. 25, 26. | −16 28.3 | Sept. 24, 26. | 62 19.0 | Sept. 25, 26. | 5.501 | .2536 | 11.84 | .5459 | Lieut. H. E. Nichols, U. S. N., assist. C. and G. S. | Th. M. III, D. C. 10. |
| 21 | Monticello. | 38 39.7 | 122 11.4 | 1880 | Oct. 5, 6, 7, 8, 9, 12. | −17 12.8 | Oct. 14, 15, 16. | 63 14.2 | Oct. 6, 7, 8, 9, 11, 12, 13. | 5.419 | .2499 | 12.03 | .5550 | J. J. Gilbert (G. Davidson). | Th. M. 10, D. C. 15. |
| 22 | Vaca. | 38 22.4 | 122 05.0 | 1880 | Nov. 18, 19, 20, 22, 23. | −17 11.6 | ............ | ...... | Nov. 23–29. | 5.476 | .2525 | .... | ... | E. F. Dickens. | Th. M. 10. |
|  | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1881 | Mar. 30, 31, Apr. 1. | −16 33.3 | Mar. 31, Apr. 1 | 62 17.6 | Mar. 30, 31, Apr. 1. | 5.537 | .2553 | 11.91 | .5491 | W. Eimbeck, R. A. Marr. | Th. M. 10, D. C. 15. |
| 23 | Sacramento. | 38 36.1 | 121 28.0 | 1881 | Apr. 5, 6, 7. | −15 51.6 | Apr. 5, 6. | 63 40.7 | Apr. 5, 6, 7. | 5.368 | .2475 | 12.11 | .5582 | do. | do. |
|  | San Diego, La Playa. | 32 42.2 | 117 14.5 | 1881 | Apr. 6. | −13 27.6 | Apr. 5, 6. | 57 51.2 | Apr. 6. | 6.104 | .2814 | 11.47 | .5289 | H. E. Nichols. | Th. M. III, D. C. 10. |
| 24 | Blue Cañon. | 39 15.3 | 120 47.0 | 1881 | Apr. 9, 10. | −15 38.4 | Apr. 9, 10. | 64 22.3 | Apr. 9, 10. | 5.260 | .2425 | 12.16 | .5607 | W. Eimbeck, R. A. Marr. | Th. M. 10, D. C. 15. |
|  | San Pedro. | 33 44.2 | 118 16.7 | 1881 | Apr. 11. | −14 27.1 | Apr. 10. | 58 48.5 | Apr. 11. | 5.991 | .2762 | 11.57 | .5333 | H. E. Nichols. | Th. M. III, D. C. 10. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Santa Barbara. | 34 24.6 | 119 41.5 | 1881 | Apr. 14. | −14 51.9 | Apr. 13. | 59 19.2 | Apr. 14. | 5.871 | .2707 | 11.51 | .5305 | do. | do. |
| | San Luis Obispo. | 35 10.6 | 120 44.5 | 1881 | Apr. 16. | −15 36.7 | Apr. 16. | 60 30.0 | Apr. 17. | 5.831 | .2689 | 11.84 | .5461 | do. | do. |
| | *Monterey.* | 36 36.2 | 121 53.8 | 1881 | Apr. 20. | −15 53.9 | Apr. 19. | 61 12.7 | Apr. 20. | 5.663 | .2611 | 11.76 | .5422 | do. | do. |
| | *Presidio, San Francisco.* | 37 47.5 | 122 27.2 | 1881 | Apr. 26, 27. | −16 31.9 | Apr. 25, 27. | 62 26.9 | Apr. 26, 27. | 5.489 | .2531 | 11.87 | .5472 | do. | do. |
| | do. | 37 47.5 | 122 27.2 | 1881 | July 12.<br>Nov. 1. | −16 30.0<br>−16 34.5 | July 11.<br>Oct. 31. | 62 28.9<br>62 34.2 | July 12.<br>Nov. 1. | 5.489<br>5.487 | .2531<br>.2530 | 11.88<br>11.91 | .5478<br>.5492 | do. | do. |
| | San Francisco, Lafayette Park | 37 47.4 | 122 25.6 | 1881 | .............. | ..... | June 3, 6, 7. | 62 17.8 | Feb. 15, 17, 18, 21, 23, 24, 26. | 5.537 | .2553 | 11.91 | .5491 | J. S. Lawson. | Th. M. 10, D. C. 21. |
| | Presidio, San Francisco. | 37 47.5 | 122 27.2 | 1881 | June 22, 23, 24.<br>Dec. 1, 2, 3. | −16 13.7<br>−16 22.7 | June 30, July 1;<br>1882, Apr. 17, 18 | 62 24.9<br>62 25.5 | June 22 to 29.<br>Dec. 2 to 9. | 5.528<br>5.531 | .2549<br>.2550 | 11.94<br>11.95 | .5505<br>.5509 | do. | do. |

COLORADO.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Denver. | 39 45.4 | 104 59.5 | 1873 | Aug. 14. | −14 42.8 | Aug. 13. | 67 27.2 | Aug. 14, 15. | 4.985 | .2298 | 13.00 | .5993 | E. Smith. | M. 6, D. C. 8. |
| 2 | Colorado Springs. | 38 50.0 | 104 49.1 | 1873 | Sept. 1, 4, 5, 6. | −14 51.8 | Aug. 30. | 66 51.4 | Sept. 3. | 5.041 | .2324 | 12.83 | .5913 | do. | do. |
| 3 | West Las Animas. | 38 04.5 | 103 01 | 1878 | Aug. 14. | −13 27.5 | ............ | ...... | ............ | .... | .... | .... | .... | J. B. Baylor. | Comp. of Th. M. 9 |
| 4 | North Pueblo. | 38 18 | 104 36.8 | 1878 | Aug. 19, 20, 21. | −13 40.0 | Aug. 20, 21, 22, 23. | 66 31.3 | Aug. 19, 20, 22, 23. | 5.183 | .2390 | 13.01 | .5999 | do. | Th. M. 9, D. C. 18. |
| | Colorado Springs. | 38 50 | 104 49 | 1878 | Aug. 26. | −14 47.3 | ............ | ...... | ............ | .... | .... | .... | .... | do. | Comp. of Th. M. 9 |
| | Denver. | 39 45.3 | 104 59.5 | 1878 | Sept. 3, 4, 5. | −14 40.2 | Sept. 4, 6. | 67 30.7 | Sept. 3, 4, 5. | 4.968 | .2291 | 12.99 | .5990 | do. | Th. M. 9, D. C. 18. |
| 5 | Greeley. | 40 25.5 | 104 40 | 1878 | Sept. 9, 10. | −14 33.7 | ............ | ...... | .... ....... | .... | .... | .... | .... | do. | Comp. of Th. M. 9 |

CONNECTICUT.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Tashua. | 41 15.6 | 73 15.0 | 1833 | Sept. 14, 16. | + 5 04 | ............ | ...... | ............ | .... | .... | .... | .... | Direction of F. R. Hassler. | Azim. Compass. |
| 2 | New Haven. | 41 18.5 | 72 55.7 | 1844 | Aug. 28. | + 5 45.1 | Aug. 27, 28. | 73 21.0 | Aug. 28, 29. | 3.818 | .1760 | 13.33 | .6143 | J. Renwick. | M. 2, Rob. D. C. of Gir. Col. |
| | do. | 41 18.3 | 72 55.5 | 1844 | .............. | ...... | Aug. 29. | 73 27.5 | ............ | .... | .... | .... | .... | do. | Robinson D. C. of Gir. Col. |
| 3 | Stamford. | 41 03.5 | 73 32.3 | 1844 | Sept. 12. | + 6 36.0 | Sept. 12. 13. | 73 02.3 | Sept. 12. | 3.885 | .1791 | 13.32 | .6139 | do. | M. 2, Rob. D. C. of Gir. Col. |
| 4 | Norwalk. | 41 07.1 | 73 24.6 | 1844 | Sept. 14. | + 6 49.4 | Sept. 14. | 73 09.8 | ............ | .... | .... | .... | .... | do. | Tr. & Simms Var. Tran. of Colum. Col., Rob. D. C. of Gir. Col. |
| 5 | Stonington. | 41 19.8 | 71 54.3 | 1845 | Aug. 8, 9. | + 7 38.1 | Aug. 8, 9. | 73 25.1 | Aug. 8, 9. | 3.748 | .1728 | 13.13 | .6055 | do. | M. 2, Rob. and Barrow D. C. |
| 6 | New London. | 41 18.4 | 72 00.3 | 1845 | Aug. 13. | + 7 29.5 | Aug. 13. | 72 57.9 | ............ | .... | .... | .... | .... | do. | do. |
| 7 | Saybrook. | 41 16.5 | 72 20.6 | 1845 | Aug. 19. | + 6 49.9 | Aug. 19. | 74 33.8 | Aug. 19. | 3.564 | .1643 | 13.39 | .6173 | do. | do. |
| 8 | Sachem's Head. | 41 16.9 | 72 43.5 | 1845 | Aug. 23. | + 6 15.2 | ............ | ...... | ............ | ... | .... | .... | .... | do. | M. 2. |
| 9 | New Haven. | 41 18.0 | 72 54.6 | 1845 | Sept. 10. | + 6 17.3 | ............ | ...... | ... ........ | .... | .... | .... | .... | do. | do. |
| 10 | Bridgeport. | 41 10 | 73 11 | 1845 | Sept. 17. | + 6 19.3 | Sept. 17. | 73 21.3 | Sept. 17. | 3.738 | .1724 | 13.05 | .6019 | do. | M. 2, Rob. and Barrow D. C. |
| 11 | Milford. | 41 14 | 73 04 | 1845 | Sept. 19. | + 6 38.3 | ............ | ...... | ............ | .... | .... | .... | .... | do. | M. 2. |
| 12 | Black Rock. | 41 08.6 | 73 12.9 | 1845 | Sept. 20. | + 6 53.5 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 13 | Fort Wooster. | 41 16.9 | 72 53.6 | 1847 | Sept. 25, 28, Oct. 1, 2. | + 7 27.2 | Sept. 28, Oct. 1, 2. | 74 16.6 | Sept. 27, 28, 30. | 3.667 | .1691 | 13.53 | .6240 | R. H. Fauntleroy. | M. 2, Rob. and Barrow D. C. |

## TABLES OF MAGNETIC RESULTS—Continued.

### CONNECTICUT—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ' | ° ' |  |  | ° ' |  | ° ' |  |  |  |  |  |  |  |
|  | New Haven. | 41 18.0 | 72 54.6 | 1848 | Aug. 10, 12, 14. | + 6 37.9 | Aug. 17, 18. | 73 31.9 | Aug. 14, 15, 16. | 3.776 | .1741 | 13.32 | .6142 | J. S. Ruth. | M. 1. |
|  | Fort Wooster. | 41 16.9 | 72 53.6 | 1848 | Aug. 21, 23, 25, 29 | + 7 25.5 | Aug. 21, 23, 25. | 74 12.6 | Aug. 25, 26. | 3.617 | .1668 | 13.29 | .6130 | do. | do. |
| 14 | New Haven, Oyster Point. | 41 17.0 | 72 55.7 | 1848 | Aug. 30, 31, Sept. 1. | + 6 31.9 | Aug. 30, 31. | 73 32.9 | Aug. 30, 31. | 3.769 | .1738 | 13.31 | .6137 | do. | do. |
|  | New Haven. | 41 16.9 | 72 55.8 | 1855 | Aug. 17. | + 7 02.7 | Aug. 17. | 73 44.5 | Aug. 17. | 3.690 | .1701 | 13.18 | .6076 | C. A. Schott. | Sm'n Inst'n M., Gambey D. C. |
| 15 | Hartford. | 41 45.9 | 72 40.5 | 1859 | July 27. | + 7 17.0 | July 27. | 74 07.4 | July 27. | 3.716 | .1713 | 13.58 | .6262 | do. | M. 6, Barrow D. C. 9. |
| 16 | Bald Hill. | 41 58.3 | 72 11.9 | 1861 | Sept. 16, 17, 18. | + 8 50.4 | Sept. 10, 12, 13, 14. | 73 47.5 | Sept. 19, 20. | 3.715 | .1713 | 13.31 | .6137 | G. W. Dean, R. E. Halter (A. D. Bache). | M. 1, D. C. 4. |
| 17 | Box Hill. | 41 47.9 | 72 27.3 | 1861 | Oct. 16, 17, 18. | + 8 30.4 | Oct. 24, 25. | 73 57.9 | Oct. 21, 22. | 3.743 | .1726 | 13.55 | .6249 | do. | do. |
| 18 | Sandford. | 41 27.7 | 72 57.0 | 1862 | Oct. 6, 7, 8. | + 7 01.7 | Sept. 30, Oct. 3. | 73 33.3 | Oct. 9, 10. | 3.855 | .1777 | 13.62 | .6277 | E. Goodfellow (A. D. Bache). | do. |
| 19 | Ivy. | 41 52.3 | 73 13.5 | 1863 | June 29, 30, July 1. | + 8 25.7 | June 23, 24, 25, 26. | 73 32.0 | July 2, 3, 17. | 3.792 | .1748 | 13.38 | .6167 | S. H. Lyman, G. W. Dean (A. D. Bache). | do. |
|  | Tashua. | 41 15.6 | 73 15.0 | 1863 | Sept. 8, 9, 11. | + 8 02.5 | Aug. 31, Sept. 1. | 73 00.8 | Sept. 16, 17. | 3.887 | .1792 | 13.30 | .6134 | do. | do. |
| 20 | Wooster. | 41 21.0 | 73 29.3 | 1864 | Aug. 2, 3, 4. | + 7 37.6 | July 20 to 28. | 73 24.6 | Aug. 5, 6. | 3.818 | .1760 | 13.37 | .6164 | R. E. Halter (A. D. Bache). | do. |
|  | Hartford. | 41 45.9 | 72 40.4 | 1867 | Aug. 15, 17. | + 7 49.3 | Aug. 17. | 73 20.5 | Aug. 15, 17. | 3.801 | .1753 | 13.26 | .6115 | C. A. Schott. | M. 1, D. C. 10. |
|  | do. | 41 45.9 | 72 40.5 | 1879 | July 24, 25, 26. | + 8 34.0 | July 24, 25. | 73 25.7 | July 24, 25. | 3.783 | .1744 | 13.26 | .6115 | J. B. Baylor. | Th. M. 9, D.C. 18. |

### DAKOTA TERRITORY.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Pembina. | 48 59 | 97 14 | 1880 | Sept. 9, 10. | −12 36.7 | Sept. 9, 10. | 77 27.9 | Sept. 9, 10. | 3.033 | .1398 | 13.97 | .6441 | J. B. Baylor. | Th. M. 9, D.C. 18. |
| 2 | Jamestown. | 46 53.2 | 98 45 | 1880 | Sept. 15, 16. | −13 30.6 | Sept. 15, 16. | 75 35.7 | Sept. 15, 16. | 3.457 | .1594 | 13.90 | .6407 | do. | do. |
| 3 | Bismarck. | 46 46.3 | 100 38 | 1880 | Sept. 21, 22. | −15 50.0 | Sept. 21, 22. | 74 55.7 | Sept. 21, 22. | 3.617 | .1668 | 13.91 | .6414 | do. | do. |
| 4 | Yankton. | 42 54 | 97 28 | 1880 | Oct. 9, 11. | −12 04.2 | Oct. 9, 11. | 72 52.2 | Oct. 9, 11. | 4.124 | .1901 | 14.00 | .6453 | do. | do. |

### DELAWARE.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cape Henlopen. | 38 46.6 | 75 05.1 | 1843 | Oct. and Nov. | + 2 26.0 | .... .... | ...... | ............ | .... | .... | .... | .... | S. P. Lee. | Azim. Compass. |
| 2 | Wilmington. | 39 44.9 | 75 33.9 | 1846 | May 27. | + 2 30.7 | May 28. | 71 25.4*<br>73 58.0 | May 28. | 4.236 | .1953 | .... | .... | John Locke. | M. 2, Robinson D. Comp. |
| 3 | Sawyer. | 39 42.1 | 75 34.0 | 1846 | June 3 | + 2 48.3 | June 3. | 71 57.5 | June 3. | 4.175 | .1925 | 13.48 | .6215 | do. | do. |

*Loca. deflection.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Fort Delaware. | 39 35.3 | 75 34.2 | 1846 | June 14. | +3 16.8 | June 14, 15 | 71 34.9 | June 15. | 4.226 | .1949 | 13.38 | .6169 | do. | do. |
| 5 | Bombay Hook. | 39 21.8 | 75 30.7 | 1846 | June 17. | +3 18.5 | June 17. | 71 39.5 | June 17. | 4.201 | .1937 | 13.35 | .6155 | do. | do. |
| 6 | Lewes Landing. | 38 48.8 | 75 11.9 | 1846 | July 1. | +2 45.0 | ………… | …… | ………… | …. | …. | …. | …. | do. | M. 2. |
| | Cape Henlopen. | 38 46.5 | 75 05.3 | 1856 | Aug. 27. | +3 03.9 | Aug. 27. | 71 22.0 | Aug. 27. | 4.285 | .1976 | 13.41 | .6184 | C. A. Schott. | M. 6, D. C. 5. |
| 7 | Dagsborough. | 38 35.0 | 75 15.6 | 1856 | Aug. 28. | +2 41.1 | Aug. 28. | 71 03.1 | Aug. 28. | 4.348 | .2005 | 13.39 | .6174 | do. | do. |
| | Wilmington. | 39 46.6 | 75 32.5 | 1875 | July 15, 21, 23. | +3 44.4 | July 17. | 71 24.0 | July 22, Oct. 4. | 4.364 | .2012 | 13.68 | .6308 | J. M. Poole. | Bache-Fund M., D. C. 19. |

## DISTRICT OF COLUMBIA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Washington, near old Coast Survey office. | 38 53.1 | 77 00.6 | 1845 | ………… | ….. | Jan., Feb., May | 71 35.3<br>32.5 | May 26. 27.<br>Nov. 7. | 4.240<br>4.233 | .1953 | 13.41<br>13.39 | .6176 | T. J. Lee. | M. 1. |
| 2 | Causten. | 38 55.5 | 77 04.5 | 1851 | June 14, 16, 17, 18, 19. | +2 11.3(?) | June 9, 10. | 71 18.9 | June 20, 21, 23. | 4.233 | .1952 | 13.21 | .6093 | G. W. Dean (A. D. Bache). | M. 1, Gambey D. C. |
| 3 | Washington, northwest of Capitol. | 38 53.6 | 77 01.0 | 1852 | ………… | …… | May 25. | 71 16.1 | May 25, June 14 | 4.267 | .1967 | 13.29 | .6125 | J. E. Hilgard. | M. 1, Barrow D.C. |
| | Washington, north of Capitol. | 38 53.6 | 77 00.6 | 1855 | July. | +2 24.0 | ………… | …… | ………… | … | …. | …. | …. | C. A. Schott. | Smith'n Inst'n M. |
| 4 | Washington, Smithsonian grounds. | 38 53 2 | 77 01.6 | 1855 | July 20. | +5 44.2* | July 31. | 71 27.0 | July 31, Sept. 7. | 4.337 | .2000 | 13.63 | .6287 | do. | Smith'n Inst'n M., Gam. D. C. |
| | Causten. | 38 55.5 | 77 04.4 | 1855 | Sept. 8, Oct. 9. | +1 04.9 | Sept. 8. | 71 30.2 | Sept. 8. | 4.250 | .1960 | 13.40 | .6178 | do. | do. |
| | do. | 38 55.5 | 77 04.5 | 1855 | Oct. 9. | +1 04.0 | ………… | …… | ………… | …. | …. | …. | …. | do. | Smith'n Inst'n M. |
| | Washington, near old Coast Survey office. | 38 53.1 | 77 00.6 | 1856 | Aug. 14, 20. | +2 21.4 | Aug. and Sept. | 71 21.7 | Aug. 4, 7, 8, 14, Sept. 24. | 4.308 | .1986 | 13.48 | .6214 | do. | M. 6, D. C. 5. |
| 5 | Washington, east of Capitol. | 38 53.3 | 77 00.5 | 1856 | Aug. 15. | +2 00.9 | Aug 15. | 71 19.6 | Aug. 15. | 4.308 | .1986 | 13.45 | .6203 | do. | do. |
| | Washington, near old Coast Survey office. | 38 53.1 | 77 00.6 | 1858 | ………… | ….. | June 2. | 71 22.6 | ………… | …. | …. | …. | …. | do. | D. C. 3. |
| | do. | 38 53.1 | 77 00.6 | 1859 | ………… | …… | June 23, July 29. | 71 24.4 | June 22, 23, July 30. | 4.307 | .1986 | 13.51 | .6229 | do. | M. 6, D. C. 9. |
| | do. | 38 53.1 | 77 00.6 | 1860 | Sept. 25, 26. | +2 26.7 | Aug. 16, 17, 18, 24. | 71 15.9 | Aug. 18, 20, Sept. 25. | 4.319 | .1991 | 13.446 | .6199 | do. | do. |
| | do. | 38 53.1 | 77 00.6 | 1861 | ………… | …… | ………… | 71 18.3 | ………… | …. | …. | … | …. | S. Walker. | D. C. 8. |
| | do. | 38 53.1 | 77 00.6 | 1862 | Aug. 18, 19. | +2 39.4 | July 21, 27,<br>Aug. 19,<br>Sept. 12, 13, 15 | 71 19.5<br>71 17.5 | July 22, Aug. 18, 19. | 4.284 | .1975 | 13.368 | .6164 | C. A. Schott. | M. 3, D. C. 8, D. C. 10. |
| | do. | 38 53.1 | 77 00.6 | 1863 | July 28. | +2 41.8 | July 18, 19. | 71 14.3 | July 28. | 4.294 | .1980 | 13.351 | .6156 | do. | M. 3, D. C. 10. |
| | do. | 38 53.1 | 77 00.6 | 1865 | ………… | …… | June 27. | 71 11.7 | ………… | …. | …. | …. | . .. | do. | D. C. 10. |
| 6 | Washington, corner Second and C streets southeast. | 38 53.1 | 77 00.2 | 1867 | Jan. to Dec. inc. | +2 48.1 | Jan. to Dec. inc | 71 06.7 | Jan. to Dec. inc | 4.321 | .1992 | 13.347 | .6153 | C. A. Schott, E. Goodfellow. | Th. M. 7, D. C. 10. |
| | do. | 38 53.1 | 77 00.2 | 1868 | Jan. to Dec. inc. | +2 51.2 | Jan. to Dec. inc | 71 03.4 | Jan. to Dec. inc | 4.334 | .1998 | 13.350 | .6154 | C. A. Schott. | do. |
| | do. | 38 53.1 | 77 00.2 | 1869 | Jan. to June inc. | +2 53.0 | Jan. to June inc | 70 57.9 | Jan. to June inc | 4.347 | .2004 | 13.328 | .6145 | do. | do. |
| | do. | 38 53.1 | 77 00.2 | 1870 | June 13, 14, 15. | +2 53.6 | June 13, 14, 15. | 70 55.3 | June 13, 14, 15 | 4.352 | .2007 | 13.315 | .6140 | do. | do. |
| | do. | 38 53.1 | 77 00.2 | 1871 | June 14, 15, 16. | +2 56.9 | June 14. 15. 16. | 70 59.9 | June 14, 15, 16. | 4.356 | .2008 | 13.378 | .6167 | do. | do. |
| | do. | 38 53.1 | 77 00.2 | 1872 | June 14, 15, 17. | +3 00.0 | June 14, 15, 17. | 71 00.6 | June 14, 15, 17. | 4.360 | .2010 | 13.399 | .6177 | do. | do. |
| | do. | 38 53.1 | 77 00.2 | 1873 | June 14, 16, 17. | +3 00.1 | June 14, 16, 17. | 70 58.5 | June 14, 16, 17. | 4.344 | .2003 | 13.326 | .6144 | do. | Th. M. 7, D.C. 34. |
| | do. | 38 53.1 | 77 00.2 | 1874 | June 13, 15, 16, July 20, 21, 22. | +3 06.3 | June 13, 15, 16. | 70 52.4 | June 13, 15, 16. | 4.349 | .2005 | 13.272 | .6119 | do. | Th. M. 7 Kew D. C. Casella 15. |
| | do. | 38 53.1 | 77 00.2 | 1875 | June 12, 14, 15. | +3 15.5 | June 12. 14, 15. | 70 51.0 | June 12, 14, 15. | 4.353 | .2007 | 13.270 | .6118 | do. | do. |
| | do. | 38 53.1 | 77 00.2 | 1876 | May 1, 2. | +3 18.8 | May 1, 2. | 70 47.3 | May 1, 2.<br>Sept. 26, 27.† | 4.357<br>4.356 | .2009 | 13.238 | .6105 | C. A. Schott.<br>F. E. Hilgard. | do.<br>M. 6. |

* Local deflection.

† Station of 1877.

## TABLES OF MAGNETIC RESULTS—Continued.

### DISTRICT OF COLUMBIA—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° | | | ° ′ | | ° ′ | | | | | | | |
| 7 | Washington, near First and B streets southeast. | 38 53.2 | 77 00.4 | 1877 | June 14, 15, 16.<br>Aug. 17. | +3 42.1<br>+3 36.8 | June 14, 15, 16. | 70 49.1 | June 14, 15, 16.<br>Aug. 14.<br>Dec. 28, 29. | 4.366<br>4.371<br>4.375 | .2015 | 13.292 | .6129 | C. A. Schott.<br>A. Braid.<br>do. | Th. M. 7, Kew D. C. Casella 15.<br>Th. M. 9. |
| | do. | 38 53.2 | 77 00.4 | 1878 | June 14, 15, 17.<br>Sept. 8. | +3 47.5<br>+3 43 | June 14, 15, 17.<br>Sept. 8. | 70 49.3<br>70 47 | June 14, 15, 17.<br>Sept. 8.<br>Dec. 14. | 4.368<br>4.361<br>4.374 | .2014 | 13.282 | .6125 | C. A. Schott.<br>[Dr. T. E. Thorpe.]<br>J. B. Baylor. | Th. M. 7, Kew, D. C. Casella 15.<br>[His own instruments.]<br>Th. M. 9. |
| | do. | 38 53.2 | 77 00.4 | 1879 | June 9, 10, 11. | +3 50.4 | June 9, 10, 11. | 70 48.4 | June 9, 10, 11. | 4.370 | .2015 | 13.292 | .6129 | W. Eimbeck, C. A. Schott. | Th. M. 7, Kew D. C. Casella 15. |
| | do. | 38 53.2 | 77 00.4 | 1880 | Apr. 3. | +3 57.2 | July 12. | 70 46.4 | July 9, 10. | 4.372 | .2016 | 13.275 | .6121 | J. B. Baylor. | Th. M. 9, D. C. Casella 18. |
| | do. | 38 53.2 | 77 00.4 | 1880 | June 12, 14, 17. | +3 57.1 | June 12, 14, 17. | 70 43.4 | June 12, 14, 17. | 4.378 | .2019 | 13.258 | .6115 | do. | Th. M. 7, D. C. Casella 20. |
| | do. | 38 53.2 | 77 00.4 | 1881 | ... .......... | .... . | ........ ... | ...... | Apr. 26. | 4.380 | .2020 | .... | .... | do. | Th. M. 9 |
| | do. | 38 53.2 | 77 00.4 | 1881 | ........... .. | ...... | June 25, Dec. 17, 23. | 70 42.8 | ........... | .... | .... | .... | .... | Lt. S. W. Very, U. S. N., act. asst. C. & G. S. | D. C. 20 |
| | do. | 38 53.2 | 77 00.4 | 1882 | June 15, 16, 17. | +3 55.4 | June 15, 16, 17. | 70 44.1 | June 15, 16, 17. | 4.364 | .2012 | 13.227 | .6099 | W. Eimbeck. | Th. M. 7, D. C. 4440. |

### FLORIDA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| 1 | Sand Key. | 24 27.2 | 81 52.7 | 1849 | Aug. 19, 20, 21. | − 5 28.8 | Aug. 18, 19. | 54 25.8 | Aug. 22. | 6.758 | .3116 | 11.62 | .5357 | J. E. Hilgard. | M. 2, Barrow D. C., of 12 in. of 9 in. |
| 2 | Cape Florida. | 25 40.4 | 80 09.8 | 1850 | Feb. 22, 23, 25. | − 4 25.2 | Feb. 22, 23. | 56 13.0 | Feb. 26. | 6.615 | .3050 | 11.90 | .5485 | do. | M. 2, 12-inch Bar. D. C. |
| 3 | Depot Key. | 29 07.5 | 83 02.1 | 1852 | Mar. 14, 15, 16. | − 5 20.5 | Mar. 23, 24. | 59 55.3 | Mar. 14, 15. | 6.179 | .2849 | 12.33 | .5685 | do. | M. 1, 10-inch Bar. D. C. |
| 4 | Saint Mark's Light-House. | 30 04.5 | 84 10.6 | 1852 | Apr. 2. | − 5 29.2 | ........... | ...... | ........... | .... | .... | .... | .... | do. | M. 1. |
| 5 | Dog Island Light. | 29 47.0 | 84 39.8 | 1853 | Apr. 1. | − 5 51.2 | ........... | ... .. | ........... | .... | .... | .... | .... | J. G. Oltmanns (F. H. Gerdes). | M. 2 |
| 6 | Saint George's Island. | 29 37.4 | 85 05.5 | 1853 | Apr. 6. | − 6 02.1 | .... ....... | ... .. | ........... | .... | .... | .... | .... | do. | do. |
| 7 | Cape San Blas. | 29 39.6 | 85 21.6 | 1854 | Jan. 31. | − 6 06.5 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 8 | Hurricane Island. | 30 04.5 | 85 39.3 | 1854 | Feb. 5. | − 6 12.2 | ........... | ...... | ........... | .... | .... | .... | .... | do. | do. |
| 9 | Cape Sable Base. | 25 07.8 | 81 02.5 | 1855 | May. | − 5 23 | .... ....... | ...... | ........... | .... | .... | .... | ... | A. D. Bache. | Azim. Comp.? |
| 10 | Fernandina. | 30 40.6 | 81 27.6 | 1857 | Apr. 20. | − 4 01.8 | Apr. 10. | 62 07.3 | Apr. 6, 20. | 5.889 | .2715 | 12.59 | .5806 | C. A. Schott. | M. 6, D. C. 9. |
| 11 | Pensacola | 30 24.6 | 87 12.9 | 1858 | June 21. | − 6 47.3 | June 23. | 61 05.9 | June 22. | 6.127 | .2825 | 12.68 | .5845 | J. G. Oltmanns (F. H. Gerdes). | M. 2. |
| 12 | Apalachicola. | 29 43.2 | 84 59.0 | 1860 | Jan. 31, Feb. 1, 2 | − 6 12.0 | Jan. 26, 27, 28. | 60 19.4 | Feb. 3, 4. | 6.185 | .2852 | 12.49 | .5768 | G. W. Dean. | M. 1, D. C. 4. |
| 13 | Key West.* | 24 33.1 | 81 48.5 | 1860 | Feb., Mar., June, Dec. | − 4 46.6 | Feb., Mar., June, Dec. | 54 37.8 | (†) | 6.752 | .3113 | 11.665 | .5378 | W. P. Trowbridge, S. Walker. | M. 6, D. C.'s 8 and 9. |
| | Pensacola. | 30 24.6 | 87 12.5 | 1861 | Jan. 8, 9 | − 6 42.2 | Jan. 5, 6. | 60 38.9 | Jan. 10, 11. | 6.151 | .2836 | 12.55 | .5786 | G. W. Dean. | M. 1, D. C. 4. |
| | Key West. | 24 33.1 | 81 48.5 | 1861 | Feb., Mar., Apr. | − 4 44.5 | Feb., Mar., Apr. | 54 36.8 | (†) | 6.749 | .3112 | 11.650 | .5372 | S. Walker, J. G. Oltmanns. | M.'s 6 and 2, D. C.'s 8 and 9. |

*Absolute observations made generally on four days each month.

†Time of observations as for declination and dip. Total force refers to annual means.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | do. | 24 33.1 | 81 48.5 | 1862 | May to Dec., inclusive. | − 4 39.9 | May to Dec., inclusive. | 54 31.0 | (†) | 6.742 | .3109 | 11.620 | .5357 | S. Walker, J. G. Oltmanns. F. F. Nes. | M. 6, D. C. 9. |
| | do. | 24 33.1 | 81 48.5 | 1863 | Monthly means. | − 4 36.8 | Monthly. | 54 31.2 | (†) | 6.740 | .3108 | 11.612 | .5353 | S. Walker. | do. |
| | do. | 24 33.1 | 81 48.5 | 1864 | do. | − 4 33.9 | do. | 54 29.0 | (†) | 6.738 | .3107 | 11.598 | .5348 | do. | do. |
| | do. | 24 33.1 | 81 48.5 | 1865 | do. | − 4 31.5 | do. | 54 28.8 | (†) | 6.729 | .3103 | 11.582 | .5340 | do. | do. |
| | do. | 24 33.1 | 81 48.5 | 1866 | Jan., Feb., Mar., Apr. | − 4 29.8 | Jan., Feb., Mar., Apr. | 54 28.6 | (†) | 6.725 | .3101 | 11.569 | .5334 | do. | do. |
| 14 | Punta Rasa. | 26 29.3 | 82 00.6 | 1866 | June 28, 29. | − 4 01.5 | July 2. | 57 12.3 | June 28. | 6.583 | .3035 | 12.15 | .5604 | A. T. Mosman. | do. |
| 15 | Turkey Creek and P. Wright stations. | 28 03.5 | 80 35.2 | 1878 | May 16, 17, 18. | − 3 09.1 | . . . . . . . . . . | . . . . . . | . . . . . . . . . . . . | . . . . | . . . . | . . . . | . . . . | R. M. Bache. | Gradienter 24, Comp. needle. |
| | Fernandina. | 30 40.3 | 81 27.3 | 1879 | Feb. 3, 4, 12. | − 2 29.7 | Feb. 3, 4, 6, 12 | 61 53.6 | Feb. 3, 4, 6, 12. | 5.858 | .2701 | 12.43 | .5733 | Lieut. S. M. Ackley, U. S. N. | Th. M. 8, D. C. 19. |
| | Key West. | 24 33.3 | 81 47.9 | 1879 | Mar. 24, 25, 26. | − 3 33.9 | Mar. 24, 25, May 7. | 54 28.6 | Mar. 24, 25, May 7. | 6.632 | .3058 | 11.41 | .5263 | S. M. Ackley. | do. |
| 16 | Bird Key. | 24 37.3 | 82 53.6 | 1880 | Jan. 12, 13, 14. | − 3 42.6 | Jan. 12, 13, 14. | 54 12.6 | Jan. 13, 14. | 6.691 | .3085 | 11.44 | .5275 | do. | Th. M. 8, D. C. —. |
| 17 | Jacksonville. | 30 21 | 81 40 | 1880 | Feb. 3. | − 2 20.2 | Feb. 3. | 61 43.2 | Feb. 3. | 5.857 | .2701 | 12.36 | .5701 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 18 | Saint Augustine. | 29 54 | 81 19 | 1880 | Feb. 11. | − 2 25.3 | Feb. 11. | 61 09.2 | Feb. 11. | 5.925 | .2732 | 12.28 | .5662 | do. | do. |
| 19 | Enterprise. | 28 52.9 | 81 14 | 1880 | Feb. 18. | − 2 46.1 | Feb. 18. | 60 07.5 | Feb. 18. | 6.053 | .2791 | 12.15 | .5603 | do. | do. |
| 20 | Eau Gallie. | 28 09.4 | 80 37 | 1880 | Feb. 25. | − 1 59.8 | Feb. 25. | 58 52.1 | Feb. 25. | 6.248 | .2881 | 12.08 | .5572 | do. | do. |
| 21 | Saint Lucie. | 27 28.9 | 80 15 | 1880 | Mar. 2. | − 2 24.9 | Mar. 2. | 58 16.8 | Mar. 2. | 6.297 | .2903 | 11.98 | .5522 | do. | do. |
| 22 | Fort Jupiter. | 26 54.5 | 80 05 | 1880 | Mar. 8. | − 2 50.7 | Mar. 8. | 57 38.5 | Mar. 8. | 6.278 | .2895 | 11.73 | .5409 | do. | do. |

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* Absolute observations made generally on four days each month.

† Time of observations as for declination and dip. Total force refers to annual means.

## GEORGIA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Savannah. | 32 05.2 | 81 05.3 | 1852 | Apr. 26, 27, 28. | − 3 40.3 | Apr. 24, 26. | 63 40.0 | Apr. 26, 27. | 5.625 | .2594 | 12.68 | .5848 | J. E. Hilgard. | M. 1, Barrow D. C. |
| 2 | Tybee Light-House. | 32 01.5 | 80 50.7 | 1852 | Apr. 30, May 2. | − 3 32.1 | Apr. 30, May 1, 2. | 63 40.8 | May 2. | 5.618 | .2590 | 12.67 | .5842 | do. | do. |
| 3 | Macon. | 32 50.4 | 83 37.5 | 1855 | Jan. 10, 11, 12, 13. | − 4 36.5 | Jan. 10, 11, 12. | 63 50.9 | Jan. 15, 16. | 5.660 | .2610 | 12.84 | .5922 | G. W. Dean. | M. 1, D. C. 4. |
| 4 | Skiddeway, North Base. | 31 56.1 | 81 01.5 | 1856 | April. | − 3 25 | . . . . . . . . . . . | . . . . . . | . . . . . . . . . . . | . . . . | . . . . | . . . . | . . . . | A. W. Longfellow. | Compass. |
| | Savannah. | 32 05.2 | 81 05.3 | 1857 | May 2. | − 3 27.5 | May 1. | 63 44.3 | May 2. | 5.664 | .2612 | 12.80 | .5903 | C. A. Schott. | M. 6, D. C. 9. |
| | Tybee Light-House. | 32 01.5 | 80 50.7 | 1870 | May 21, 22, 23, 24. | − 2 20.5 | May 25, 26. | 63 27.0 | May 21, 24. | 5.682 | .2620 | 12.71 | .5861 | C. O. Boutelle. | M. 3, D. C. 6. |
| 5 | Butler. | 31 17.7 | 81 20.8 | 1872 | Mar. 12, 13, 14, 18. | − 2 42.9 | Apr. 15, 16. | 62 46.7 | Mar. 15, 16. | 5.779 | .2665 | 12.63 | .5825 | A. T. Mosman. | M. 3, D. C. 8. |
| 6 | Middle Base, near Atlanta. | 33 54.4 | 84 16.7 | 1872 | Oct. 28, 29, 31, Nov. 1. | − 3 30.1 | Nov. 4, 5. | 64 55.6 | Oct., Nov. | 5.507 | .2539 | 13.00 | .5992 | F. P. Webber. | M. 3, D. C. 5. |
| | do. | 33 54.4 | 84 16.7 | 1873 | Feb. 12, 13. | − 3 34.9 | Feb. 12, 13. | 64 58.5 | Feb. 8, 9. | 5.489 | .2531 | 12.98 | .5983 | do. | do. |
| 7 | Kenesaw. | 33 58.6 | 84 34.8 | 1873 | Aug. 1, 2, 3. | − 4 43.4 | Aug. 1, 2, 3. | 66 00.2 | Aug. 1, 2, 3. | 5.424 | .2501 | 13.34 | .6149 | do. | M. 3, D. C. 10. |
| 8 | Sweat. | 34 04.0 | 84 27.4 | 1873 | Oct. 9, 10. | − 5 36.9 | Oct. 9, 10. | 65 29.2 | Oct. 9, 10. | 5.455 | .2515 | 13.15 | .6062 | do. | M. 3, D. C. 8. |
| 9 | Sawnee. | 34 14.2 | 84 09.7 | 1873 | Oct. 30, 31, Nov. 1, 3. | − 2 55.0 | Nov. 12, 14. | 65 26.0 | Nov. 1, 3, 4. | 5.412 | .2495 | 13.02 | .6002 | C. O. Boutelle. | do. |
| 10 | Cumming. | 34 12.4 | 84 07.7 | 1873 | Nov. 10, 11, 12. | − 3 13.5 | Nov. 15, 18. | 65 23.5 | Nov. 10, 11. | 5.461 | .2518 | 13.11 | .6047 | H. W. Blair (C. O. Boutelle). | do. |
| 11 | Carnes. | 33 59.6 | 85 00.8 | 1873 | Dec. 20, 21, 22. | − 4 05.5 | Dec. 20, 21, 22. | 65 09.6 | Dec. 20, 21, 22. | 5.468 | .2521 | 13.02 | .6001 | F. P. Webber. | do. |
| | Savannah. | 32 05.2 | 81 05.3 | 1874 | Mar. 8, 9, 10. | − 2 16.9 | Mar. 9, 10. | 63 53.9 | Mar. 5, 9, 10. | 5.558 | .2563 | 12.63 | .5825 | C. Tappan (F. Blake). | Bache-Fund, M., D. C. 35. |
| 12 | Grassy. | 34 29.2 | 84 20.0 | 1874 | July 22, 23, 24. | − 3 36.0 | July 29, 31. | 65 41.8 | July 24, 25. | 5.192 | .2394 | 12.62 | .5817 | C. O. Boutelle. | Th. M. 8, D. C. 10. |
| 13 | Pine Log. | 34 19.3 | 84 38.3 | 1874 | Aug. 10, 11, 12. | − 4 00.0 | Aug. 10, 11, 12 | 65 33.0 | Aug. 10, 11, 12. | 5.422 | .2500 | 13.10 | .6040 | F. P. Webber. | M. 3, D. C. 8. |

## TABLES OF MAGNETIC RESULTS—Continued.

### GEORGIA—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  |  |  |  |  |  |  |  |  |
| 14 | Skitt. | 34 30.3 | 83 43.4 | 1874 | Aug. 14, 15, 17, 18. | − 2 35.5 | ........... | ...... | ............ | .... | .... | .... | .... | C. O. Boutelle. | Th. M. 8. |
| 15 | Currahee. | 34 31.8 | 83 22.6 | 1874 | Oct. 19, 20, 21, 22. | − 2 47.9 | Nov. 10, 11. | 65 45.1 | Oct. 26, 27, Nov. 9. | 5.282 | .2435 | 12.86 | .5929 | do. | Th. M. 8, D. C. 10. |
| 16 | Academy, Lawrenceville. | 33 57.5 | 83 59.5 | 1874 | Dec. 7, 8, 9. | − 3 24.8 | ............ | ...... | ............ | ... | .... | .... | .... | do. | Th. M. 8. |
| 17 | Lavender. | 34 19.3 | 85 17.4 | 1874 | Dec. 10, 11, 12. | − 3 58.9 | Dec. 10, 11, 12. | 65 30.7 | Dec. 10, 11, 12. | 5.430 | .2500 | 13.10 | .6040 | F. P. Webber. | M. 3, D. C. 8. |
| 18 | Johns. | 34 37.4 | 85 06.0 | 1875 | Jan. 20, 22, 23, 24. | − 3 57.1 | June 22, 23, 24. | 65 42.5 | June 22, 23, 24. | 5.401 | .2490 | 13.13 | .6054 | do. | do. |
| 19 | Du Pont or Lawton. | 30 57.8 | 82 47 | 1880 | Jan. 29. | − 2 26.0 | Jan. 29. | 62 07.3 | Jan. 29. | 5.841 | .2693 | 12.49 | .5759 | J. B. Baylor. | Th. M. 9, D. C. 18. |

### IDAHO TERRITORY.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Siniaquoteen. | 48 10.5 | 116 45 | 1881 | Sept. 5, 6. | −22 28.5 | Sept. 6. | 72 30.7 | Sept. 5, 6. | 3.969 | .1830 | 13.21 | .6090 | J. S. Lawson. | Th. M. 8, D. C. 21. |
| 2 | Lake Pend d'Oreille, landing. | 47 58 | 116 30 | 1881 | Sept. 10, 11, 12. | −22 05.4 | Sept. 11. | 72 26.0 | Sept. 10, 11. | 4.006 | .1847 | 13.27 | .6120 | do. | do. |
| 3 | Lewiston. | 46 28 | 117 05 | 1881 | Sept. 16, 17, 18. | −21 26.2 | Sept. 16, 17. | 70 52.0 | Sept. 18. | 4.275 | .1971 | 13.04 | .6014 | do. | do. |

### ILLINOIS.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Mound City. | 37 04.8 | 89 04.2 | 1865 | Jan. 3. | − 7 32 | ............ | ...... | ............ | .... | .... | .... | .... | A. T. Mosman. | Azim. Comp. |
| 2 | Cairo. | 36 59.8 | 89 10.2 | 1865 | Apr. 13. | − 6 41 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
|  | do. | 37 01.0 | 89 10.5 | 1877 | Nov. 28, 29, 30. | − 6 00.4 | Nov. 28, 29, 30. | 67 45.6 | Nov. 28, 29, 30. | 5.058 | .2332 | 13.36 | .6162 | A. Braid. | Th. M. 9, D. C. 18. |
| 3 | Springfield. | 39 50 | 89 39 | 1878 | Dec. 4, 5. | − 5 48.8 | Dec. 3, 6, 7. | 70 25.5 | Dec. 4, 5. | 4.497 | .2073 | 13.42 | .6187 | J. B. Baylor. | do. |

### INDIANA.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | New Harmony. | 38 08 | 87 50 | 1848 | Nov. 14, 15, 16, 17. | − 6 47.0 | Nov. 13. | 69 07.2 | Nov. 12. | 4.843 | .2233 | 13.59 | .6265 | R. H. Fauntleroy. | M. 2. |
|  | do. | 38 08 | 87 50 | 1861 | Apr. 11, 12, 13. | − 6 43.5 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Eng.'s Transit with needle. |
| 2 | Vincennes. | 38 41.7 | 87 31.6 | 1880 | Oct. 29, 30. | − 4 22.5 | Oct. 30. | 69 50.4 | Oct. 29, 30. | 4.632 | .2136 | 13.44 | .6198 | J. B. Baylor. | Th. M. 9, D. C. 18. |
|  | New Harmony. | 38 08 | 87 50 | 1880 | Nov. 3, 5. | − 5 05.1 | Nov. 3, 5. | 69 02.6 | Nov. 3, 5. | 4.762 | .2196 | 13.31 | .6140 | do. | do. |
| 3 | Indianapolis. | 39 47.4 | 86 08 | 1880 | Nov. 12, 13. | − 2 47.0 | Nov. 12, 13. | 70 51.4 | Nov. 12, 13. | 4.370 | .2015 | 13.33 | .6144 | do. | do. |
| 4 | Richmond. | 39 50.4 | 84 50 | 1880 | Nov. 19, 20. | − 2 52.5 | Nov. 19. | 71 13.4 | Nov. 19, 20. | 4.354 | .2008 | 13.53 | .6238 | do. | do. |

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Vinita. | 36 39.5 | 95 05.0 | 1877 | Nov. 22, 23, 24. | − 9 24.8 | Nov. 22, 23, 24. | 66 31.8 | Nov. 22, 23, 24. | 5.284 | .2436 | 13.27 | .6117 | A. Braid. | Th. M. 9, D. C. |
| 2 | Atoka. | 34 24.5 | 96 05 | 1878 | July 14, 15, 16. | − 9 11.4 | July 13, 15, 16, 17. | 63 44.8 | July 13, 15, 16. | 5.670 | .2614 | 12.82 | .5910 | J. B. Baylor. | do. |
| 3 | Eufaula. | 35 16 | 95 33 | 1878 | July 18. | − 9 10.3 | ............ | ...... | ............ | ... | .... | .... | .... | do. | Comp. to Th. M |

## IOWA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Des Moines. | 41 35.0 | 93 37.4 | 1869 | Aug. | − 9 56 | Aug. | 71 13 | Aug. 9. | 4.313 | .1989 | 13.40 | .6177 | J. E. Hilgard. | ? |
| 2 | Sibley. | 43 24.1 | 95 50.0 | 1877 | Oct. 8, 9, 10. | −10 50.3 | Oct. 8, 9, 10. | 72 59.3 | Oct. 8, 9, 10. | 4.053 | .1869 | 13.85 | .6388 | A. Braid. | Th. M. 9, D. C. 18. |
| | Des Moines. | 41 36.8 | 93 36.5 | 1877 | Oct. 23, 24, 25. | − 9 23.5 | Oct. 23, 24, 25. | 71 31.0 | Oct. 23, 24, 25. | 4.330 | .1996 | 13.66 | .6296 | do. | do. |
| 3 | Davenport. | 41 29.9 | 90 38.0 | 1877 | Oct. 27, 29, 30. | − 7 02.8 | Oct. 27, 28, 29, 30. | 71 56.6 | Oct. 27, 29, 30. | 4.274 | .1971 | 13.79 | .6359 | do. | do. |
| 4 | Keokuk. | 40 25.5 | 91 25.0 | 1877 | Nov. 6, 7, 8. | − 7 29.8 | Nov. 6, 7, 8. | 70 47.2 | Nov. 6, 7, 8. | 4.506 | .2078 | 13.69 | .6315 | do. | do. |
| 5 | Dubuque. | 42 29.5 | 90 44 | 1880 | Oct. 21, 22. | − 6 45.8 | Oct. 21, 22. | 73 07.8 | Oct. 21, 22. | 3.972 | .1831 | 13.69 | .6310 | J. B. Baylor. | do. |

## KANSAS.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lawrence. | 38 57.7 | 95 15.0 | 1877 | Nov. 14, 15, 16, 17. | − 9 51.6 | Nov. 14, 15, 16, 17. | 68 43.4 | Nov. 14, 15, 16, 17. | 4.866 | .2244 | 13.41 | .6184 | A. Braid. | Th. M. 9, D. C. 18. |
| 2 | Humboldt. | 37 49 | 95 26 | 1878 | July 20. | −10 04.9 | ............ | ..... | ............ | .... | .... | .... | .... | J. B. Baylor. | Comp. to Th. M. 9. |
| 3 | Emporia. | 38 25.5 | 96 12 | 1878 | July 23. | −10 50.4 | ............ | ..... | ............ | .... | .... | .... | .... | do. | do. |
| 4 | Great Bend. | 38 23.6 | 98 43.1 | 1878 | July 30, 31, Aug. 1. | −11 05.0 | July 30, 31, Aug. 2. | 67 38.0 | July 30, Aug. 1. | 4.988 | .2300 | 13.11 | .6044 | do. | Th. M. 9, D. C. 18. |
| 5 | Dodge City. | 37 44 | 99 58.9 | 1878 | Aug. 5. | −12 16.4 | ............ | ..... | ............ | .... | .... | .... | .... | do. | Comp. to Th. M. 9. |
| 6 | Sargent. | 38 05.2 | 101 58.5 | 1878 | Aug. 9, 10. | −12 44.3 | Aug. 8, 12. | 66 50.5 | Aug. 10. | 5.129 | .2365 | 13.04 | .6014 | do. | Th. M. 9, D. C. 18. |

## KENTUCKY.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Paducah. | 37 04.6 | 88 36.8 | 1865 | Feb. 7. | − 6 45 | ............ | ..... | ............ | .... | .... | .... | .... | A. T. Mosman. | Azim. Compass. |
| 2 | Upper Point Rocks. | 37 03.5 | 88 17.0 | 1865 | Feb. 16. | − 7 25 | ............ | ..... | ............ | .... | .... | .... | .... | do. | do. |
| 3 | Twenty-seven Mile Island. | 36 57.2 | 88 13.9 | 1865 | Feb. 24. | − 7 22 | ............ | ..... | ............ | .... | .... | .... | .... | do. | do. |
| 4 | Patterson's Landing. | 37 03.2 | 88 25.2 | 1865 | Mar. 6. | − 6 44 | ............ | ..... | ............ | .... | .... | .... | .... | do. | do. |
| 5 | Oakland. | 37 02.4 | 86 15.3 | 1871 | Nov. 7, 8, 9. | − 6 14.2 | Nov. 6. | 68 48.8 | Nov. 10. | 4.877 | .2249 | 13.49 | .6222 | A. T. Mosman, E. Smith. | M. 3, D. C. 4. |
| 6 | Shelbyville. | 38 12.8 | 85 13.2 | 1871 | Nov. 23, 24, 25. | − 3 02.7 | Nov. 28, Dec. 2. | 69 46.6 | Nov. 27, 29, 30. | 4.660 | .2149 | 13.48 | .6216 | do. | M. 1 and No. 3, D. C. 4. |
| 7 | Falmouth. | 38 40.8 | 84 17.3 | 1872 | Jan. 3, 4, 5. | − 3 21.4 | Dec. 30, '71; Jan. 2, 3. | 70 16.1 | Jan. 8, 9. | 4.580 | .2112 | 13.57 | .6255 | E. Goodfellow. | M. 1, D. C. 4. |
| 8 | Hickman. | 36 34.3 | 89 11.7 | 1881 | Sept. 23, 24. | − 5 47.3 | Sept. 23, 24. | 67 19.4 | Sept. 23, 24. | 5.071 | .2338 | 13.15 | .6064 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 9 | Mayfield. | 36 45 | 88 41 | 1881 | Sept. 27, 28. | − 5 12.9 | Sept. 27, 28. | 67 35.0 | Sept. 27, 28. | 5.008 | .2309 | 13.13 | .6055 | do. | do. |
| 10 | Madisonville. | 37 19 | 87 33 | 1881 | Oct. 4, 5. | − 5 06.2 | Oct. 4, 5. | 68 24.2 | Oct. 4, 5. | 4.915 | .2266 | 13.35 | .6157 | do. | do. |
| 11 | Leitchfield. | 37 30 | 86 22 | 1881 | Oct. 7, 8. | − 3 19.3 | Oct. 7, 8. | 68 38.2 | Oct. 7, 8. | 4.892 | .2256 | 13.43 | .6193 | do. | do. |
| 12 | Lebanon. | 37 36 | 85 19 | 1881 | Oct. 11, 12. | − 3 43.9 | Oct. 11, 12. | 69 06.8 | Oct. 11, 13. | 4.750 | .2190 | 13.32 | .6143 | do. | do. |
| 13 | Stanford. | 37 31 | 84 44 | 1881 | Oct. 15, 16. | − 4 15.8 | Oct. 15, 16. | 69 43.8 | Oct. 15, 17. | 4.625 | .2132 | 13.35 | .6154 | do. | do. |
| 14 | Livingston. | 37 23 | 84 20 | 1881 | Oct. 20, 21. | − 1 36.6 | Oct. 20, 21. | 68 50.3 | Oct. 20, 21. | 4.817 | .2221 | 13.34 | .6152 | do. | do. |
| 15 | Cynthiana. | 38 26 | 84 25 | 1881 | Oct. 25, 26. | − 2 28.4 | Oct. 25, 26. | 69 44.0 | Oct. 25, 26. | 4.626 | .2133 | 13.36 | .6158 | do. | do. |
| 16 | Flemingsburg. | 38 26 | 83 46 | 1881 | Oct. 31, Nov. 1. | − 1 45.3 | Oct. 31, Nov. 1. | 69 45.2 | Oct. 31, Nov. 1. | 4.627 | .2133 | 13.37 | .6164 | do. | do. |
| 17 | Grayson. | 38 18 | 82 59 | 1881 | Nov. 5, 6. | − 1 27.5 | Nov. 5, 6. | 70 09.3 | Nov. 5, 6. | 4.643 | .2141 | 13.68 | .6307 | do. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### LOUISIANA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Fort Livingston. | 29 16.4 | 89 56.7 | 1853 | Jan. 9. | − 7 38.4 | ........ .. | ...... | ............ | .... | . . | .... | .... | F. H. Gerdes, J. G. Oltmanns. | M. 2. |
| 2 | Isle Dernier. | 29 02.0 | 90 54.2 | 1853 | Feb. 20. | − 8 19.2 | ............ | ...... | ............ | .. | .... | .... | .... | do. | do. |
| 3 | Barrel Key. | 29 54.3 | 89 08.0 | 1857 | .............. | ......... | Apr. 14. | 59 48.2 | Apr. 18. | 6.282 | .2897 | 12.49 | .5759 | S. Harris. | M. 2, D. C. 8. |
| 4 | New Orleans. | 29 57.4 | 90 04.4 | 1858 | Apr. 6, 7. | − 7 51.5 | Apr. 7, 8, 10. | 59 46.5 | Apr. 7, 8. | 6.310 | .2909 | 12.54 | .5779 | G. W. Dean. | M. 1, D. C. 4. |
| 5 | Cubitt. | 29 09.9 | 89 14.6 | 1859 | Dec. 15. | − 7 31.8 | Dec. 16. | 58 54.0 | Dec. 16. | 6.342 | .2924 | 12.28 | .5662 | F. H. Gerdes, J. G. Oltmanns. | M. 2, D. C. 8. |
| 6 | Southeast Pass. | 29 04.7 | 89 03.6 | 1859 | .............. | ..... | Dec. 21. | 58 45.3 | Dec. 21. | 6.377 | .2940 | 12.29 | .5669 | do. | do. |
| 7 | Pass à Loutre. | 29 10.9 | 89 01.4 | 1859 | Dec. 27. | − 7 30.0 | Dec. 27. | 58 47.0 | Dec. 27. | 6.355 | .2930 | 12.26 | .5654 | do. | do. |
| 8 | Côte Blanche. | 29 44.1 | 91 42.9 | 1860 | Mar. 3. | − 8 21.5 | Mar. 3. | 59 08.8 | Mar. 4. | 6.349 | .2927 | 12.38 | .5709 | do. | do. |
| 9 | New Orleans. | 29 59.1 | 90 04.8 | 1872 | Feb. 10, 12, 14, 15. | − 6 39.6 | Feb. 12, 15. | 59 46.0 | Feb. 10, 15. | 5.959 | .2748 | 11.84 | .5458 | T. C. Hilgard. | Bache-Fund M. |
| 10 | Magnolia Base, lower station. | 29 32.5 | 89 46.6 | 1872 | Jan. 18, 19, 20, 21. | − 6 46.8 | Jan. 17. | 59 23.5 | Jan. 17 | 5.977 | .2756 | 11.74 | .5413 | do. | do. |
| 11 | Southwest Pass. | 28 59 | 89 23 | 1872 | Mar. 2. | − 6 05.4 | Mar. 2, 3. | 58 47.0 | Mar. 2, 3. | 6.221 | .2868 | 12.00 | .5534 | do. | do. |
| | New Orleans. | 29 59.1 | 90 04.8 | 1880 | Mar. 24, 25. | − 6 27.6 | Mar. 24, 25. | 59 48.8 | Mar. 24, 25. | 6.155 | .2838 | 12.24 | .5644 | J. B. Baylor. | Th. M. 9, D. C. 18. |

### MAINE.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| 1 | Agamenticus. | 43 13.4 | 70 41.5 | 1847 | Sept. 23, 25, 28, 29, 30, Oct. 1, 2. | +10 09.8 | Nov. 2, 4. | 74 54.7 | Sept. 29, Oct. 4. | 3.456 | .1593 | 13.28 | .6120 | T. J. Lee, R. H. Fauntleroy. | M. 1, Robinson & Barrow D. C. |
| 2 | Waterville. | 44 33 | 69 45 | 1849 | .............. | ...... | June, Jul., Aug. | 75 59.4 | Aug. | 3.243 | .1495 | 13.40 | .6175 | G. W. Keeley. | D. C. 3. |
| 3 | Mount Independence. | 43 45.5 | 70 19.2 | 1849 | Oct. 6, 7, 8, 9. | +11 46.4 | Oct. 9, 15, 16. | 75 23.8 | Oct. 12, 13. | 3.422 | .1578 | 13.57 | .6259 | G. Davidson. | M. 1, Gambey D. C. |
| 4 | Kittery Point, opposite Portsmouth, N. H. | 43 04.8 | 70 43.0 | 1850 | Aug. 28, 29, 31, Sept. 1, 2. | +10 30.2 | Aug. 29, Sept. 3. | 74 57.2 | Sept. 4. | 3.500 | .1614 | 13.48 | .6217 | J. E. Hilgard. | M. 2, Barrow D. C. |
| 5 | Fletcher's Neck. | 43 26.8 | 70 20.5 | 1850 | Sept. 10, 11, 12. | +11 17.5 | Sept. 9, 10. | 75 18.3 | Sept. 11, 12. | 3.440 | .1586 | 13.56 | .6252 | do. | do. |
| 6 | Richmond Island. | 43 32.6 | 70 14.4 | 1850 | Sept. 14, 15, 16. | +12 18.1 | Sept. 14, 16. | 75 08.0 | Sept. 16. | 3.464 | .1597 | 13.50 | .6224 | do. | do. |
| 7 | Portland, Bramhall or Bowdoin Hill. | 43 38.8 | 70 16.6 | 1851 | Aug. 18, 19, 20. | +11 41.1 | Aug. 15, 19. | 75 14.1 | Aug. 20. | 3.450 | .1591 | 13.54 | .6243 | do. | do. |
| 8 | Mount Pleasant. | 44 01.6 | 70 49.3 | 1851 | Aug. 21, 22, 23, 24, 25. | +14 32.1 | Aug. 6, 7. | 76 01.5 | Aug. 25, 26, 27. | 3.212 | .1481 | 13.30 | .6133 | G. W. Dean. | M. 1, Bar. D. C., of Sm'n Inst. |
| 9 | Kennebunkport. | 43 21.4 | 70 28.1 | 1851 | Aug. 25, 26, 27. | +11 23.6 | Aug. 23. | 75 14.1 | Aug. 27. | 3.448 | .1590 | 13.53 | .6239 | J. E. Hilgard. | M. 2, Bar. D. C. |
| 10 | Cape Neddick. | 43 11.6 | 70 36.4 | 1851 | Aug. 29, 30, 31. | +11 09.0 | Aug. 29, 30. | 74 57.9 | Aug. 28. | 3.516 | .1621 | 13.55 | .6249 | do. | do. |
| 11 | Cape Small. | 43 46.7 | 69 50.7 | 1851 | Oct. 16, 17, 18, 20. | +12 05.5 | Oct. 16, 17, 18. | 75 01.8 | Oct. 21, 23, 24, 25. | 3.389 | .1563 | 13.12 | .6051 | G. W. Dean (A. D. Bache). | M. 1, Bar. D. C., of Sm'n Inst. |
| 12 | Mount Sebattis. | 44 09.1 | 70 04.8 | 1853 | July 25, 26, 27. | +12 53.5 | July 29. | 75 40.6 | July 25, 27. | 3.411 | .1573 | 13.79 | .6358 | J. E. Hilgard (A. D. Bache). | M. 2, Gambey D. C. |
| 13 | Mount Ragged. | 44 12.8 | 6 09.1 | 1854 | Sept. 27, 28, 29, 30 | +14 16.8 | Sept. 22, 23. | 75 41.2 | Sept. 25, 26. | 3.345 | .1542 | 13.53 | .6237 | G. W. Dean, S. Harris | M. 1, D. C. 4. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Camden Village. | 44 12 | 69 05 | 1854 | Oct. 26, 27, 28, 29, 30, 31, Nov. 1. | +13 57.1 | Oct. 27, 28. | 75 41.5 | Nov. 2, 3, 4. | 3.345 | .1542 | 13.54 | .6239 | G. W. Dean, R. J. Breckinridge. | do. |
| 15 | Mount Harris. | 44 39.9 | 69 08.9 | 1855 | Sept. 3, 4, 5, 6. | 14 34.6 | Sept. 4, 5, 6, 11. | 76 14.1 | Sept. 7, 8. | 3.240 | .1494 | 13.62 | .6279 | G. W. Dean, T. M. McIver. | do. |
| 16 | Mount Saunders. | 44 39.0 | 68 36.5 | 1856 | July 8, 9, 10, 11. | 14 59.4 | July 8, 9, 11, 17. | 75 58.6 | Sept. 12, 14. | 3.279 | .1512 | 13.53 | .6240 | G. W. Dean, J. H. Toomer. | do. |
| 17 | Southwest Harbor, Mount Desert Island. | 44 15.0 | 68 17.6 | 1856 | Sept. 25, 26, 27, 29, 30. | 15 25.2 | Sept. 26. | 76 15.5 | Sept. 27. | 3.280 | .1512 | 13.81 | .6365 | S. Harris. | do. |
| 18 | Mount Desert. | 44 21.1 | 68 13.6 | 1856 | Oct. 7, 8, 9, 13. | 15 14.2 | Oct. 8, 9, 11. | 76 09.2 | Oct. 10, 11. | 3.255 | .1501 | 13.60 | .6272 | G. W. Dean. | do. |
| 19 | Epping Base, east end. | 44 40.1 | 67 49.9 | 1857 | Summer. | 16 20 | ... ........ | ..... | ........... | .... | .... | ... | .... | C. O. Boutelle. | Compass. |
| 20 | Calais. | 45 11.0 | 67 16.8 | 1857 | Sept. 16, 17, 18, 19. | 15 21.1 | Sept. 18, 19. | 76 25.5 | Sept. 22, 23. | 3.231 | .1490 | 13.76 | .6348 | G. W. Dean, S. Harris | M. 1, D. C. 4. |
| 21 | Bangor, Thomas Hill. | 44 48.2 | 68 46.9 | 1857 | Oct. 13, 14, 15. | 15 19.9 | Oct. 12, 13, 16. | 76 14.7 | Oct. 10. | 3.231 | .1490 | 13.59 | .6267 | G. W. Dean, S. Harris, H. W. Bache. | do. |
| 22 | Humpback. | 44 51.8 | 68 06.6 | 1858 | Aug. 24, 25, 26. | 15 47.8 | Aug. 24, Sept. 15. | 76 12.0 | Aug. 27, 30. | 3.220 | .1485 | 13.50 | .6225 | G. W. Dean, A. T. Mosman (A. D. Bache). | do. |
| | Kittery Point. | 43 04.8 | 70 43.0 | 1859 | July 14. | 11 15.0 | July 14. | 75 04.2 | July 14. | 3.496 | .1612 | 13.57 | .6257 | C. A. Schott. | M. 6, D. C. 9. |
| | Portland, Bramhall Hill. | 43 38.8 | 70 16.6 | 1859 | July 15. | 12 20 | July 15. | 74 56.7 | July 15. | 3.456 | .1593 | 13.31 | .6133 | do. | do. |
| 23 | Howard. | 44 37.7 | 67 23.7 | 1859 | Aug. 9, 10, 11. | 18 31.6 | Aug. 3, 6, 10. | 75 21.6 | Aug. 12, 13. | 3.458 | .1594 | 13.68 | .6307 | G. W. Dean (A. D. Bache). | M. 1, D. C. 4. |
| 24 | Cooper. | 44 59.2 | 67 28.0 | 1859 | Sept. 9, 10, 12, 13. | 16 31.9 | Sept. 10, 13. | 76 20.3 | Sept. 14, 15. | 3.180 | .1466 | 13.46 | .6207 | do. | do. |
| 25 | Eastport, Fort Sullivan. | 44 54.4 | 66 59.2 | 1860 | Aug., Sept., Oct., Nov., Dec.* | 17 57.1 | Jan. to Dec. inclusive.* | 75 53.1 | Jan. to Dec. inclusive.* | 3.307 | .1525 | 13.56 | .6253 | G. B. Vose. | Th. M. 7, D. C. 10. |
| | do. | 44 54.4 | 66 59.2 | 1861 | Monthly, Jan. to Dec. incl. | 17 59.2 | Monthly, Jan. to Dec. incl. | 75 51.0 | Monthly, Jan. to Dec. incl. | 3.307 | .1525 | 13.53 | .6238 | G. B. Vose, S. Walker | do. |
| | do. | 44 54.4 | 66 59.2 | 1862 | Monthly, Jan. to Dec. incl. | 18 00.6 | Monthly. | 75 48.5 | Monthly. | 3.303 | .1523 | 13.47 | .6212 | S. Walker, R. H. Talcott, E. Goodfellow. | do. |
| | do. | 44 54.4 | 66 59.2 | 1863 | Monthly, Jan. to Dec. incl. | 18 02.3 | Monthly. | 75 48.3 | Monthly. | 3.310 | .1526 | 13.50 | .6223 | E. Goodfellow. | do. |
| 26 | Portland, Munjoy's Hill. | 43 39.9 | 70 14.9 | 1863 | July 6. | 12 18.1 | July 6. | 75 04.6 | July 6. | 3.425 | .1579 | 13.30 | .6132 | C. A. Schott. | M. 3, D. C. 8. |
| 27 | Rockland. | 44 06.3 | 69 06.2 | 1863 | July 7. | 15 02.1 | July 7. | 75 30.9 | July 7. | 3.318 | .1530 | 13.26 | .6116 | do. | do. |
| 28 | Belfast. | 44 26.0 | 69 00.8 | 1863 | July 8. | 15 30.3 | July 8. | 75 38.1 | July 8. | 3.330 | .1535 | 13.42 | .6189 | do. | do. |
| | Bangor, Thomas Hill. | 44 48.2 | 68 46.9 | 1863 | ........ ..... | ...... | July 10. | 76 05.3 | July 10. | 3.208 | .1479 | 13.34 | .6152 | do. | do. |
| 29 | Bath. | 43 54.9 | 69 49.0 | 1863 | July 11. | 12 51.8 | July 11. | 75 25.5 | July 11. | 3.355 | .1547 | 13.33 | .6147 | do. | do. |
| 30 | Freeport. | 43 51.1 | 70 05.9 | 1863 | July 13. | 14 11.7 | July 13. | 75 20.3 | July 13. | 3.395 | .1565 | 13.41 | .6184 | do. | do. |
| | Portland, Bramhall Hill. | 43 38.8 | 70 16.6 | 1863 | July 15. | 12 28.2 | July 15. | 75 05.9 | July 15. | 3.439 | .1586 | 13.37 | .6166 | do. | do. |
| 31 | Harpswell. | 43 44.5 | 70 00.8 | 1863 | July 22. | 14 25.5 | July 22. | 75 52.4 | July 22. | 3.184 | .1468 | 13.04 | .6015 | do. | do. |
| | Eastport. | 44 54.4 | 66 59.2 | 1864 | Monthly, Jan. to July incl.* | 18 03.7 | Jan. to July inclusive.* | 75 45.8 | Jan. to July inclusive.* | 3.313 | .1528 | 13.48 | .6213 | E. Goodfellow, A. T. Mosman, H. W. Richardson. | Th. M. 7, D. C. 10. |
| | Portland, Bramhall Hill. | 43 38.8 | 70 16.6 | 1864 | Monthly, Aug. to Dec. incl.* | 12 43.7 | Aug. to Dec. inclusive.*† | 75 09.5 | Aug to Dec. inclusive.*† | 3.456 | .1593 | 13.49 | .6219 | H. W. Richardson. | do. |
| | Eastport. | 44 54.4 | 66 59.2 | 1865 | July 22, 23, 24, 25. | 18 06.1 | July 22, 23, 24, 25. | 75 44.7 | July 22, 23, 24, 25. | 3.317 | .1529 | 13.47 | .6210 | do. | do. |
| | Portland, Bramhall Hill. | 43 38.8 | 70 16.6 | 1865 | Monthly, Jan. to Dec. incl.* | 12 42.3 | Jan. to Dec. inclusive.*† | 75 08.3 | Jan. to Dec. inclusive.*† | 3.459 | .1595 | 13.49 | .6219 | do. | do. |
| | do. | 43 38.8 | 70 16.6 | 1866 | Jan., Feb., Mar.* | +12 42.9 | Jan., Feb., Mr.* | 75 07.4 | Jan., Feb., Mr.* | 3.458 | .1594 | 13.47 | .6209 | do. | do. |

* On four days each month, 1860 to 1866 inclusive.

† Monthly.

## TABLES OF MAGNETIC RESULTS—Continued.

### MAINE—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
|  | Eastport. | 44 54.3 | 66 59.3 | 1873 | Sept. 2, 3. | +18 56.0 | Aug. 28, 31, Sept. 1, 4. | 75 24.3 | Sept. 2, 3. | 3.363 | .1551 | 13.35 | .6155 | T. C. Hilgard. | Th. M. 7, D. C. 10. |
|  | Portland, Munjoy's Hill. | 43 39.9 | 70 14.9 | 1873 | Sept. 8, 9, 11. | 12 43.6 | Sept. 8, 10, 11. | 74 57.9 | Sept. 8, 9, 11. | 3.472 | .1601 | 13.38 | .6171 | do. | do. |
| 32 | Brunswick. | 43 54.5 | 69 57.7 | 1873 | Sept. 15, 16. | 14 18.0 | Sept. 16, 17. | 75 08.3 | Sept. 13, 15, 16 | 3.437 | .1585 | 13.40 | .6179 | do. | do. |
|  | Kittery Point. | 43 04.8 | 70 43.0 | 1879 | Aug. 13, 14. | 12 31.3 | Aug. 13, 14. | 74 26.2 | Aug. 13, 14. | 3.588 | .1654 | 13.37 | .6165 | J. B. Baylor. | Th. M. 9, D. C. 18. |
|  | Bangor. | 44 48.2 | 68 46.9 | 1879 | Aug. 21. | 16 29.3 | Aug. 21. | 75 29.8 | Aug. 21. | 3.317 | .1529 | 13.24 | .6105 | do. | do. |
|  | Eastport. | 44 54.4 | 66 59.2 | 1879 | Aug. 27, 28. | +19 07.8 | Aug. 27, 28. | 75 12.2 | Aug. 27, 28. | 3.404 | .1570 | 13.33 | .6148 | do. | do. |

### MARYLAND.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
| 1 | Taylor. | 38 59.8 | 76 28.0 | 1845 | May 31, June 1. | + 2 14.4 | June 1. | 71 40.2 | May 31. | 4.231 | .1951 | 13.45 | .6204 | Capt. T. J. Lee, U. S. E., Act'g Asst. C. S. | M. 1, Fox D. C., by Patten. |
| 2 | South base, Kent Island. | 38 53.9 | 76 22.0 | 1845 | June 3, 4. | 2 24.3 | June 3. | 71 37.0 | June 4. | 4.206 | .1939 | 13.34 | .6149 | T. J. Lee. | M. 1, Fox D. C. |
| 3 | Rosanne. | 39 17.5 | 76 43.1 | 1845 | June 10. | 2 10.9 | June 11. | 72 06.6 | June 10. | 4.053 | .1869 | 13.19 | .6084 | do. | do. |
| 4 | Finlay. | 39 24.4 | 76 31.5 | 1845 | June 13, 14. | 2 14.6 | June 14. | 71 52.9 | June 13. | 4.059 | .1872 | 13.05 | .6020 | do. | do. |
| 5 | Osborne's Ruin. | 39 27.9 | 76 16.9 | 1845 | June 19, 21, 22, 23, 24. | 2 32.4 | June 30, July 3. | 71 47.6 | June 25, July 2. | 4.143 | .1910 | 13.26 | .6113 | do. | do. |
|  | Finlay. | 39 24.4 | 76 31.5 | 1846 | April 16. | 2 18.5 | Apr. 10, 11, 16. | 71 47.9 | Apr. 14. | 4.113 | .1896 | 13.17 | .6070 | T. J. Lee, J. Locke. | M. 1, Robinson D. C., Robinson D Comp. |
| 6 | Marriott. | 38 52.4 | 76 36.6 | 1846 | May 24, 25, 26, 27, June 3, 4, 5. | 2 09.4 | May 27. | 71 10.9 | June 2, 4. | 4.260 | .1964 | 13.21 | .6089 | T. J. Lee .......... | M. 1, Rob. D. C. |
| 7 | North Point. | 39 11.7 | 76 26.7 | 1846 | July 7, 8. | 1 36.7 | July 8. | 71 29.5 | July 7. | 4.183 | .1929 | 13.18 | .6077 | do. | do. |
| 8 | Bodkin Light. | 39 08.0 | 76 25.5 | 1847 | April 25, 26. | 2 01.9 | Apr. 25, 26. | 71 43.1 | Apr. 25. | 4.189 | .1931 | 13.35 | .6156 | do. | M. 1, Fox D. C., by George. |
|  | North Point. | 39 11.7 | 76 26.7 | 1847 | April 27. | 1 39.6 | ........... | ...... | ........... | .... | .... | .... | .... | do. | M. 1. |
|  | Taylor. | 38 59.8 | 76 28.0 | 1847 | May 28, 29, 30, 31, June 1, 2, 3. | 2 18.0 | June 5. | 71 19.3 | May 28, June 1. | 4.222 | .1947 | 13.18 | .6079 | do. | M. 1, Rob. D. C., of Gir. Col. |
| 9 | Fort McHenry, Baltimore. | 39 15.8 | 76 34.8 | 1847 | April 29. | 2 18.6 | ........... | ...... | ........... | .... | ... | .... | .... | do. | M. 1. |
| 10 | Pool's Island. | 39 17.1 | 76 15.8 | 1847 | June 24, 25, 26, 27. | 2 29.3 | June 23, 29, July 1. | 71 52.1 | June 26, 28. | 4.117 | .1898 | 13.23 | .6099 | do. | M. 1, Rob. D. C., of Gir. Col. |
| 11 | Susquehanna Light. | 39 32.4 | 76 05.1 | 1847 | July 6, 7. | 2 13.7 | July 6, 7. | 71 52.1 | July 7, 8. | 4.086 | .1884 | 13.13 | .6054 | do. | do. |
|  | Marriott. | 38 52.4 | 76 36.6 | 1849 | June 12, 13, 19, 20. | 2 05.0 | June 1, 7, 8, 9. | 71 12.9 | June 13, 15, 16. | 4.332 | .1997 | 13.45 | .6202 | A. D. Bache, J. Hewston. | M. 1, Gambey D. C. |
| 12 | Kent Island, Station 1. | 39 01.8 | 76 19.1 | 1849 | June 27, 28, 29, 30, July 2, 3, 4. | 2 30.2 | June 29, July 2, 4. | 71 16.6 | June 27, 30, July 5, 9. | 4.307 | .1986 | 13.42 | .6187 | J. Hewston. | do. |
| 13 | Soper. | 39 05.2 | 76 57.0 | 1850 | July 20, 21, 22, 24, 25, 26. | + 2 07.1 | July 23, 24, 25. | 71 56.5 | July 22, 23, 24. | 4.144 | .1911 | 13.37 | .6165 | G. W. Dean (A. D. Bache). | do. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | Hill. | 38 53.9 | 76 52.8 | 1850 | Sept. 19, 20, 21, 22 | + 2 18.6 | Sept. 18, 20, 21. | 71 12.2 | Sept. 23, 24, 25, 27. | 4.317 | .1990 | 13.40 | .6176 | do. | do. |
| 15 | Webb. | 39 05.3 | 76 40.5 | 1850 | Nov. 20, 21, 22, 23 | 2 07.9 | Nov. 20, 21, 22. | 71 24.0 | Nov. 25, 26, 27, 28. | 4.280 | .1973 | 13.42 | .6186 | do. | do. |
| 16 | Davis. | 38 20.4 | 75 06.4 | 1853 | Sept. 25, 27. | 2 33.0 | Sept. 21. | 70 57.7 | Sept. 25. | 4.332 | .1997 | 13.28 | .6122 | J. E. Hilgard. | M. 2, Gam. D.C., of Land Office. |
| 17 | Oxford. | 38 41.4 | 76 10.5 | 1856 | Aug. 23. | 2 41.3 | Aug. 23. | 70 58.0 | Aug. 23. | 4.384 | .2021 | 13.44 | .6197 | C. A. Schott. | M. 6, D. C. 5. |
| 18 | Mason's Landing. | 38 13.8 | 75 15.0 | 1856 | Aug. 30. | 2 22.8 | Aug. 30. | 70 44.8 | Aug. 30. | 4.406 | .2032 | 13.36 | .6162 | do. | do. |
| | Fort McHenry. | 39 15.9 | 76 34.9 | 1856 | Sept. 13. | 2 29.3 | Sept. 13. | 71 45.8 | Sept. 13. | 4.203 | .1938 | 13.43 | .6193 | do. | do. |
| 19 | Cumberland. | 39 39.2 | 78 45.4 | 1864 | Mar. 21. | 1 31.9 | ............ | ...... | ............ | .... | ... | .... | .... | A. T. Mosman. | M. 1. |
| | Webb. | 39 05.3 | 76 40.5 | 1868 | Sept. 24, 25, 26, 27. | 2 55.6 | Sept. 23, 24, 28. | 71 18.5 | Sept. 23, 24. | 4.337 | .2000 | 13.53 | .6240 | C. O. Boutelle. | M. 3, D. C. 6. |
| | Hill. | 38 53.9 | 76 52.8 | 1868 | Oct. 27, 28, Nov. 3, 4. | 2 51.1 | Oct. 27, 28, 29. | 71 17.1 | Oct. 27, 28. | 4.378 | .2019 | 13.64 | .6291 | do. | do. |
| 20 | Stabler. | 39 07.2 | 76 59.1 | 1869 | Aug. 18 to 31, Sept. 1. | 2 39.9? | Aug. 25, 27, 28. | 71 28.1 | Aug. 24, 25, 26. | 4.287 | .1977 | 13.49 | .6220 | do. | do. |
| 21 | Maryland Heights. | 39 20.4 | 77 43.0 | 1870 | Oct. 12 to 30, Nov. 2 to 16. | 2 56.0 | Oct. 25, 26, 27, 28. | 71 28.0 | Oct. 17, 18, Nov. 5, 6. | 4.324 | .1994 | 13.60 | .6273 | do. | M. 3, D. C. 8. |
| 22 | Calvert | 38 21.5 | 76 23.6 | 1871 | Aug. 1, 2, 3. | 2 48.9 | July 31. | 70 33.9 | Aug. 4. | 4.485 | .2068 | 13.48 | .6215 | A. T. Mosman. | do. |
| | Fort McHenry. | 39 15.9 | 76 34.9 | 1877 | Oct. 10, 11, 12. | + 4 10.8 | Oct. 13. | 71 36.5 | Oct. 11, 12. | 4.246 | .1958 | 13.46 | .6206 | J. B. Baylor. | Bache-fund M, D. C. 19. |

## MASSACHUSETTS.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Copecut. | 41 43.3 | 71 03.6 | 1844 | Sept. 27 to Oct. 17; 15 days. | + 9 08.8 | Oct. 3, 4. | 74 09.5 | ............ | .... | .. | .... | .... | T. J. Lee. | Gam. Decl'n Transit of Gir. Col. |
| 2 | Indian. | 41 25.7 | 70 40.6 | 1845 | July 23 to Aug 2; 10 days. | 8 43.9 | Aug. 5. | 73 41.4 | July 30, Aug. 4 | 3.734 | .1722 | 13.29 | .6132 | do. | M. 1, Fox D. C. by Patten. |
| 3 | Shootflying. | 41 41.1 | 70 20.8 | 1845 | Aug. 15 to 22; 8 days. | 9 37.4 | Aug. 28, Sept. 2 | 74 23.3 | Aug. 25, 26. | 3.657 | .1686 | 13.59 | .6265 | do. | do. |
| 4 | Manomet. | 41 55.6 | 70 35.5 | 1845 | Sept. 9, 10, 11. | 9 16.9 | Sept. 12. | 74 30.0 | Sept. 12. | 3.640 | .1678 | 13.62 | .6279 | do. | do. |
| 5 | Blue Hill. | 42 12.7 | 71 06.9 | 1845 | Sept. 28, 29, 30, Oct. 2, 4, 5. | 9 13.5 | Oct. 8. | 75 05.6 | Sept. 29, 30, Oct. 2. | 3.519 | .1623 | 13.68 | .6309 | do. | do. |
| 6 | Fairhaven. | 41 37.4 | 70 54.1 | 1845 | Oct. 17, 18, 19. | 8 54.2 | Oct. 17. | 74 40.0 | Oct. 16. | 3.592 | .1656 | 13.58 | .6262 | do. | do. |
| 7 | Sampson's Hill. | 41 22.7 | 70 29.0 | 1846 | July 22, 23, 24, 25, 26, 27. | 8 48.7 | July 22, 24, Aug. 15. | 73 24.5 | July 25, 27. | 3.753 | .1730 | 13.14 | .6059 | do. | M. 1, Barrow D. C. |
| 8 | Nantucket. | 41 17.5 | 70 06.0 | 1846 | July 30, 31. | 9 14.0 | July 29, Aug. 2 | 73 44.1 | July 30, 31. | 3.653 | .1684 | 13.04 | .6014 | do. | do. |
| 9 | Tarpaulin Cove. | 41 28.1 | 70 45.4 | 1846 | Aug. 7, 8, 9. | 9 12.1 | Aug. 7, 8. | 73 49.8 | Aug. 8. | 3.696 | .1704 | 13.27 | .6119 | do. | do. |
| | Indian. | 41 25.7 | 70 40.7 | 1846 | Aug. 12, 13. | 8 49.4 | Aug. 11, 12. | 73 29.1 | Aug. 13. | 3.728 | .1719 | 13.12 | .6047 | do. | do. |
| 10 | Hyannis. | 41 37.9 | 70 18.4 | 1846 | Aug. 24, 25, 26. | 9 21.6 | Aug. 22, 24. | 73 49.2 | Aug. 24, 25. | 3.682 | .1698 | 13.21 | .6094 | T. J. Lee, R. H. Fauntleroy. | do. |
| | Shootflying. | 41 41.1 | 70 20.8 | 1846 | Aug. 28, 29, 30. | 9 40.3 | Aug. 28, 30 | 73 56.5 | Aug. 29. | 3.663 | .1689 | 13.24 | .6106 | do. | do. |
| | Manomet. | 41 55.6 | 70 35.5 | 1846 | .............. | ..... | Sept. 1. | 74 01.2 | ............ | .... | .... | .... | .... | R. H. Fauntleroy. | Barrow D. C. |
| 11 | Dorchester or South Boston Heights. | 42 20.0 | 71 02.6 | 1846 | Sept. 6, 7, 8. | 9 31.4 | Sept. 3, 5. | 74 12.7 | Sept. 6, 7. | 3.587 | .1654 | 13.18 | .6079 | T. J. Lee, R. H. Fauntleroy. | M. 1, Barrow D. C. |
| 12 | Nantasket. | 42 18.2 | 70 54.3 | 1847 | Sept. 1, 2, 3. | 9 37.4 | Sept. 3. | 74 15.9 | Sept. 1, 2. | 3.566 | .1644 | 13.15 | .6062 | T. J. Lee. | M. 1, Rob. and Bar. D. C. |
| 13 | Little Nahant. | 42 26.2 | 70 55.8 | 1849 | Aug. 15, 16, 17. | + 9 40.9 | Aug. 14, 17. | 74 29.5 | Aug. 13, 14, 17. | 3.556 | .1640 | 13.30 | .6134 | G. W. Keeley. | M. 13, D. C. 3. |

## TABLES OF MAGNETIC RESULTS—Continued.

### MASSACHUSETTS—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
| 14 | Fort Lee, Salem. | 42 31.9 | 70 52.5 | 1849 | Aug. 20. | +10 14.5 | ………… | ………… | Aug. 18. | 3.487 | .1608 | …. | …. | G. W. Keeley. | M. 13. |
| 15 | Beaconhill, Gloucester. | 42 36.2 | 70 38.6 | 1849 | Aug. 24, 25, 27. | 11 21.1 | Aug. 22, 23, 25. | 74 26.4 | Aug. 21, 22, 25. | 3.617 | .1668 | 13.48 | .6218 | do. | M. 13, D. C. 3. |
| 16 | Annisquam. | 42 39.4 | 70 40.6 | 1849 | Aug. 28. | 11 36.7 | ………… | ………… | ………… | … | …. | …. | …. | do. | M. 13. |
| 17 | Baker's Island Light. | 42 32.2 | 70 47.2 | 1849 | Sept. 1, 3, 4. | 12 17.0 | Aug. 31, Sept. 1, 3. | 74 18.6 | Sept. 1, 3. | 3.682 | .1698 | 13.62 | .6279 | do. | M. 1, D. C. 3. |
| 18 | Coddon's Hill. | 42 30.9 | 70 51.3 | 1849 | Sept. 6, 7, 8. | 11 49.8 | ………… | ………… | ………… | …. | …. | …. | …. | do. | M. 1. |
| 19 | Plum Isl'd, near Newburyport. | 42 48.0 | 70 48.8 | 1850 | Sept. 18, 19, 20. | 10 05.6 | Sept. 19. | 74 54.9 | Sept. 18. | 3.530 | .1628 | 13.56 | .6255 | J. E. Hilgard. | M. 2, Bar. D. C. |
|  | Nantucket. | 41 17.5 | 70 06.0 | 1855 | Aug. 22. | 9 58.4 | Aug. 22. | 74 00.6 | Aug. 22. | 3.626 | .1672 | 13.16 | .6069 | C. A. Schott. | Smithsonian Inst. M., Gam. D. C. |
|  | Dorchester or South Boston Heights. | 42 20.0 | 71 02.6 | 1855 | Aug. 24. | 10 13.7 | Aug. 24. | 74 29.5 | Aug. 24. | 3.544 | .1634 | 13.26 | .6111 | do. | do. |
|  | Fort Lee, Salem. | 42 31.9 | 70 52.5 | 1855 | Aug. 25. | 10 49.7 | Aug. 25. | 75 36.9 | Aug. 25. | 3.489 | .1609 | 14.04 | .6476 | do. | do. |
|  | Beaconhill, Gloucester. | 42 36.2 | 70 38.6 | 1859 | July 8. | 12 03 | July 8. | 74 45.6 | July 8. | 3.645 | .1681 | 13.86 | .6395 | do. | M. 6, D. C. 9. |
| 20 | Thompson. | 42 36.7 | 70 43.8 | 1859 | July 9. | 11 09 | July 9. | 74 30.4 | July 9. | 3.674 | .1694 | 13.75 | .6342 | do. | do. |
| 21 | Rockport. | 42 39.6 | 70 36.6 | 1859 | July 11. | 11 37 | July 11. | 75 05.9 | July 11. | 3.529 | .1627 | 13.72 | .6327 | do. | do. |
|  | Annisquam. | 42 39.4 | 70 40.6 | 1859 | ………… | …… | July 11. | 74 56.1 | July 11. | 3.589 | .1655 | 13.81 | .6368 | do. | do. |
| 22 | Ipswich. | 42 40.8 | 70 50.1 | 1859 | July 12. | 11 14 | July 12. | 74 37.3 | July 12. | 3.598 | .1659 | 13.57 | .6256 | do. | do. |
|  | Plum Island. | 42 48.0 | 70 48.8 | 1859 | July 13. | 10 58 | July 13. | 74 52.9 | July 13. | 3.528 | .1627 | 13.53 | .6238 | do. | do. |
| 23 | Deerfield. | 42 33 | 72 36 | 1859 | July 23. | 9 25 | July 23. | 74 35.3 | July 23. | 3.617 | .1668 | 13.61 | .6277 | do. | do. |
| 24 | Chesterfield. | 42 24 | 72 51 | 1859 | July 25. | 8 54 | July 25. | 74 21.2 | July 25. | 3.667 | .1691 | 13.60 | .6270 | do. | do. |
| 25 | Springfield. | 42 06 | 72 32 | 1859 | July 26. | 8 39 | July 26. | 74 14.9 | July 26. | 3.691 | .1702 | 13.60 | .6270 | do. | do. |
| 26 | Chatham. | 41 40.2 | 69 56.9 | 1860 | Sept. 10, 11. | 11 11.6 | Sept. 10, 11. | 73 46.2 | Sept. 10, 11. | 3.744 | .1726 | 13.39 | .6175 | do. | do. |
| 27 | Wellfleet. | 41 56.1 | 70 01.8 | 1860 | Sept. 12. | 10 43.5 | Sept. 12, 13. | 74 20.2 | Sept. 12, 13. | 3.638 | .1677 | 13.48 | .6211 | do. | do. |
| 28 | Provincetown. | 42 03.2 | 70 11.1 | 1860 | Sept. 14, 15. | 11 23.5 | Sept. 14, 15. | 74 09.7 | Sept. 14, 15. | 3.656 | .1686 | 13.40 | .6177 | do. | do. |
| 29 | Wachusett. | 42 29.2 | 71 53.2 | 1860 | Sept. 19, 20, 21. | 8 48.0 | Oct. 1, 6, 10. | 74 28.8 | Sept. 27, 28, 29, Oct. 2. | 3.633 | .1675 | 13.58 | .6260 | G. W. Dean, R. E. Halter (A. D. Bache). | M. 1, D. C. 4. |
| 30 | Easthampton. | 42 15 | 72 40 | 1862 | July 7, 8, 9. | 9 04.4 | July 7, 8. | 74 06.1 | July 10, 11. | 3.691 | .1702 | 13.47 | .6213 | E. Goodfellow (A. D. Bache). | do. |
| 31 | Nantucket Cliff. | 41 17.2 | 70 06.3 | 1867 | May 28, 29, 3 June 1. | 10 19.9 | May 28, June 1. | 73 37.6 | May 30, June 5. | 3.749 | .1729 | 13.30 | .6132 | C. O. Boutelle. | M. 3, D. C. 8. |
|  | Manomet. | 41 55.6 | 70 35.5 | 1867 | July 27, 28, 29, 30, Aug. 1, 3, 5. | 10 24.6 | Aug. 7, 8, 9, 10. | 73 58.5 | Aug. 13, 21, 22. | 3.760 | .1734 | 13.62 | .6280 | do. | do. |
|  | South Boston. | 42 20.0 | 70 02.4 | 1872 | Sept. 28, 30, Oct. 1. | 11 15.2 | Sept. 27. | 73 30.5? | Sept. 30 to Oct. 5. | 3.675 | .1694 | 12.95? | .5967? | A. H. Scott, E. Goodfellow. | M. 6, D. C. 4. |
|  | Nantucket Bluff. | 41 17.3 | 70 06.3 | 1875 | Sept. 15, 16. | 11 24.0 | Sept. 16. | 73 24.1 | Sept. 15, 17. | 3.817 | .1760 | 13.36 | .6161 | J. M. Poole. | Bache-Fund M., D. C. 19. |
| 32 | Vineyard Haven. | 41 27.9 | 70 35.5 | 1875 | Sept. 21, 22. | 10 34.2 | Sept. 21, 22. | 73 09.9 | Sept 21, 22. | 3.893 | .1795 | 13.44 | .6198 | do. | do. |
|  | Nantucket Cliff. | 41 17.2 | 70 06.3 | 1879 | July 31, Aug. 2. | 11 27.9 | July 31, Aug. 2. | 73 15.1 | July 31, Aug. 2. | 3.799 | .1752 | 13.18 | .6080 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 33 | Cambridge. | 42 22.8 | 71 07.6 | 1879 | Aug. 7, 9. | +11 46.3 | Aug. 7, 9. | 73 48.4 | Aug. 7, 9. | 3.707 | .1709 | 13.29 | .6128 | do. | do. |

MICHIGAN.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Sault de St. Marie and Fort Brady. | 46 29.9 | 84 20.1 | 1880 | July 11, 13, 14, 17, 19. | + 0 53.7 | ............ | ...... | July 11, 13, 19. | 3.000 | .1383 | .... | .... | Lieut. S. W. Very, U. S. N., act. ass't C. and G. S. | Bache-Fund M. |
| 2 | Grand Haven. | 43 04.7 | 86 12.6 | 1880 | July 20, 21. | − 2 25.7 | July 20, 21. | 73 53.7 | July 20, 21. | 3.847 | .1774 | 13.87 | .6395 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 3 | Mackinac. | 45 51 | 84 40 | 1880 | July 28, 29. | + 0 20.5 | July 28, 29. | 76 27.6 | July 28, 29. | 3.264 | .1505 | 13.94 | .6428 | do. | do. |
| | Sault de St. Marie. | 46 29.9 | 84 20.1 | 1880 | Aug. 6, 7. | + 1 04.5 | Aug. 6, 7. | 77 24.0 | Aug. 6, 7. | 3.056 | .1409 | 14.01 | .6459 | do. | do. |
| 4 | Ontonagon. | 46 52.2 | 89 31 | 1880 | Aug. 16, 17. | − 4 41.5 | Aug. 16, 17. | 77 16.6 | Aug. 16, 17. | 3.094 | .1427 | 14.05 | .6479 | do. | do. |
| 5 | Kalamazoo. | 42 17.4 | 85 35.1 | 1880 | Dec. 21. | − 2 46 | ............ | ...... | ............ | .... | .... | .... | ... | Marcus Baker. | Surv.'s Comp. |

MINNESOTA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Minneapolis. | 44 58.6 | 93 14.1 | 1877 | Sept. 28, 29, 30, Oct. 1, 2. | −10 13.4 | Sept. 28, 29, 30, Oct. 1, 2. | 74 45.2 | Sept. 28, 29, 30, Oct. 1, 2. | 3.662 | .1688 | 13.92 | .6419 | A. Braid. | Th. M. 9, D. C. 18. |
| 2 | Brainerd. | 46 21.0 | 94 15 | 1880 | Aug. 29, 31, Sept. 1 | − 9 35.2 | Aug. 31, Sept. 1 | 75 42.5 | Aug. 31, Sept. 1 | 3.422 | .1578 | 13.86 | .6392 | J. B. Baylor. | do. |
| 3 | Glyndon. | 46 52.4 | 96 40 | 1880 | Sept. 4, 6. | −11 26.6 | Sept. 4, 6. | 75 48.2 | Sept. 4, 6. | 3.415 | .1575 | 13.92 | .6422 | do. | do. |
| 4 | Fort Snelling Reservation. | 44 53.5 | 93 11 | 1880 | Sept. 28, 29. | −10 13.7 | Sept. 28, 29. | 74 55.6 | Sept. 28, 29. | 3.619 | .1669 | 13.92 | .6418 | do. | do. |
| 5 | Heron Lake. | 43 47.6 | 95 24 | 1880 | Oct. 4, 5. | −10 13.8 | Oct. 4, 5. | 73 31.2 | Oct. 4, 5. | 3.924 | .1809 | 13.83 | .6377 | do. | do. |

MISSISSIPPI.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | East Pascagoula. | 30 20.7 | 88 32.8 | 1847 | June 18, 19, 20. | − 7 12.6 | ............ | ...... | June 22, 23. | 6.220 | .2868 | 12.61 | .5816 | R. H. Fauntleroy, J. S. Ruth. | M. 2. |
| | do. | 30 20.7 | 88 32.8 | 1848 | .............. | ...... | June 1, 4. | 60 27.2 | ............ | .... | .... | .... | .... | G. Davidson. | New Barrow D. C. |
| | do. | 30 20.7 | 88 32.9 | 1855 | Jan. 23, 24, 25. | − 7 08.9 | ............ | ..... | Jan. 24, Feb. 3. | 6.250 | .2882 | .... | .... | J. E. Hilgard. | M. 2. |
| 2 | Mississippi City. | 30 22.9 | 89 02.0 | 1855 | Mar. 29. | − 7 21.8 | ............ | ...... | Mar. 27, 28. | 6.195 | .2856 | .... | .... | J. E. Hilgard, J. S. Harris. | do. |

MISSOURI.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cape Girardeau. | 37 17.9 | 89 32.9 | 1865 | Mar. 18. | − 6 35 | ............ | ...... | ............ | .... | .... | .... | .... | A. T. Mosman. | Surv.'s Comp. |
| 2 | Wittemberg. | 37 39.3 | 89 33.2 | 1865 | Apr. 4. | − 6 47 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |

NEBRASKA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Omaha. | 41 15.7 | 95 56.5 | 1869 | Jan. 25, 26, 27, Feb. 12, 13. | −10 42.6 | Jan. 25, 26, 27, 28, 30, Feb. 1. | 71 04.5 | Jan. 28, 29. | 4.314 | .1990 | 13.30 | .6136 | E. Goodfellow. | M. 1, D. C. 8. |
| | do. | 41 15.7 | 95 56.5 | 1877 | Oct. 13, 15, 16, 17, 18. | −10 22.0 | Oct. 13, 15, 16, 17, 20. | 71 05.8 | Oct. 13, 15, 16, 17, 18. | 4.408 | .2032 | 13.61 | .6272 | A. Braid. | Th. M. 9, D. C. 18. |
| | do. | 41 15.7 | 95 56.5 | 1880 | Oct. 15, 17. | −10 06.2 | Oct. 15, 17. | 71 05.9 | Oct. 15, 17. | 4.375 | .2017 | 13.50 | .6227 | J. B. Baylor. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### NEVADA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Verdi. | 39 31.1 | 119 57.8 | 1872 | July 5, 6, 7. | −17 29.5 | July 29. | 63 58.6 | July 28, 29. | 5.303? | .2445 | 12.09? | .5573 | G. Davidson, S. R. Throckmorton. | Th. M. III, D. C. 12. |
| 2 | Reno. | 39 30.5 | 119 48.7 | 1881 | Apr. 11, 12, 13. | −17 48.7 | Apr. 11, 12. | 64 14.1 | Apr. 11, 12, 13. | 5.317 | .2452 | 12.23 | .5641 | W. Eimbeck, R. A. Marr. | Th. M. 10, D. C. 15. |
| 3 | Hot Springs. | 39 46.9 | 118 55.5 | 1881 | Apr. 15, 16. | −17 26.6 | Apr. 15, 16. | 64 46.5 | Apr. 15, 16. | 5.271 | .2430 | 12.37 | .5702 | do. | do. |
| 4 | Rye Patch. | 40 26.0 | 118 18.5 | 1881 | Apr. 18, 19, 20. | −17 49.7 | Apr. 18, 19. | 65 23.9 | Apr. 18, 19. | 5.159 | .2379 | 12.39 | .5714 | do. | do. |
| 5 | Winnemucca. | 40 58.9 | 117 44.0 | 1881 | Apr. 21, 22. | −17 38.8 | Apr. 21, 22. | 65 59.2 | Apr. 21, 22. | 5.114 | .2358 | 12.57 | .5794 | do. | do. |
| 6 | Battle Mountain. | 40 40.3 | 116 50.0 | 1881 | Apr. 23, 24, 25. | −17 34.8 | Apr. 23, 24. | 65 51.2 | Apr. 23, 24, 25. | 5.116 | .2359 | 12.51 | .5767 | do. | do. |
| 7 | Elko. | 40 47.4 | 115 45.5 | 1881 | Apr. 26, 27, 28. | −17 30.8 | Apr. 26, 27. | 66 23.0 | Apr. 26, 27, 28. | 5.043 | .2325 | 12.59 | .5804 | do. | do. |
| 8 | Wells Station. | 41 07.0 | 114 56.0 | 1881 | Apr. 29, 30. | −17 21.8 | Apr. 29, 30. | 66 49.9 | Apr. 29, 30. | 4.989 | .2300 | 12.68 | .5846 | do. | do. |
| 9 | Tecoma. | 41 19.5 | 114 06.0 | 1881 | May 1, 2. | −17 28.2 | May 1, 2. | 67 08.0 | May 1, 2. | 4.947 | .2281 | 12.73 | .5870 | do. | do. |
| 10 | Eureka (Town). | 39 31.1 | 115 58.2 | 1881 | May 19, 21, 22. | −16 36.6 | May 19, 21. | 65 08.4 | May 19, 21, 22. | 5.218 | .2406 | 12.41 | .5723 | do. | do. |
| 11 | Mineral Hill. | 40 09.8 | 116 12.0 | 1881 | May 23, 24, 25. | −17 03.2 | May 23, 24. | 65 40.7 | May 23, 24, 25. | 5.151 | .2375 | 12.51 | .5767 | do. | do. |
| 12 | Austin. | 39 28.9 | 117 04.0 | 1881 | May 31, June 1, 2. | −16 57.0 | May 31, June 1. | 64 49.0 | June 1, 2. | 5.254 | .2423 | 12.34 | .5694 | do. | do. |
| 13 | Mount Callahan Station. | 39 42.6 | 116 57.0 | 1881 | July 12 to 16. | −17 04.0 | July 15, 16, 20. | 65 07.4 | July 12 to 16. | 5.221 | .2407 | 12.41 | .5722 | do. | do. |
| 14 | Eureka Station. | 39 35.1 | 115 49.1 | 1881 | Sept. 13, 14, 15. | −16 49.7 | Sept. 15, 16, 29. | 65 12.3 | Sept. 13, 14, 15, 16. | 5.209 | .2402 | 12.42 | .5727 | do. | do. |
| 15 | White Pine Station. | 38 19.1 | 115 30.1 | 1881 | Nov. 14 15, 19. | −16 04.1 | Nov. 15, 22, 23. | 64 04.1 | Nov. 14, 15, 19, 22. | 5.389 | .2485 | 12.32 | .5683 | do. | do. |

### NEW HAMPSHIRE.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| 1 | Isles of Shoals, Hog Island. | 42 59.2 | 70 36.8 | 1847 | Aug. 12, 13, 15, 16, 17, 19. | +10 03.5 | Aug. 26, 27. | 74 44.1 | Aug. 17, 18. | 3.482 | .1605 | 13.22 | .6096 | T. J. Lee. | M. 1, Robinson & Barrow D. C. |
| 2 | Unkonoonuc. | 42 59.0 | 71 35.3 | 1848 | Oct. 6, 7, 8. | + 9 04.1 | Oct. 9, 10. | 75 08.7 | Oct. 9, 10. | 3.476 | .1603 | 13.56 | .6253 | J. S. Ruth. | M. 1. |
| 3 | Patuccawa. | 43 07.2 | 71 11.8 | 1849 | Aug. 15, 16, 17, 18, 19. | +10 42.8 | Aug. 16, 18, 19. | 76 49.5 | Aug. 15, 17. | 3.093 | .1426 | 13.57 | .6257 | C. O. Boutelle. | M. 1, Gambey D. C. |
| 4 | Gunstock. | 43 31.1 | 71 22.2 | 1860 | July 16, 17, 18, 19, 20. | +10 54.1 | July 28, 31, Aug. 2, 3, 4. | 75 43.6 | July 25, 26, 27. | 3.401 | .1568 | 13.80 | .6360 | G. W. Dean (A. D. Bache). | M. 6, D. C. 9. |
| 5 | Monadnock. | 42 51.7 | 72 06.5 | 1861 | ............... | ...... | July 31, Aug. 2, 3. | 74 44.4 | ............ | .... | .... | ... | .... | G. W. Dean, R. E. Halter (A. D. Bache). | D. C. 4. |
| 6 | Troy. | 42 49.7 | 72 10.9 | 1861 | Aug. 20, 21. | + 9 03.3 | Aug. 19, 20. | 74 45.7 | Aug. 21, 22. | 3.578 | .1650 | 13.61 | .6278 | do. | M. 1, D. C. 4. |
| 7 | Gorham. | 44 22.5 | 71 15.0 | 1873 | Sept. 22, 25. | +13 47.0 | Sept. 20, 22, 24, 25. | 75 35.6 | Sept. 20, 22. | 3.410 | .1572 | 13.70 | .6318 | T. C. Hilgard. | Th. M. 7, D. C. 10. |
| 8 | Littleton. | 44 19.0 | 71 48.0 | 1873 | Sept. 28, 30, Oct. 1. | +12 35.1 | Sept. 28, 29, 30. | 75 39.1 | Sept. 28, 30, Oct. 1. | 3.378 | .1558 | 13.63 | .6287 | do. | do. |
| 9 | Hanover. | 43 42.3 | 72 17.1 | 1873 | Oct. 4, 6, 9, 10, 11. | +10 49.9 | Oct. 9, 10. | 75 21.1 | Oct. 4, 6, 8, 10. | 3.455 | .1593 | 13.66 | .6299 | do. | do. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | Chesterfield. | 42 54.0 | 72 26.0 | 1874 | Oct. 4. | +10 26.6 | Oct. 4. | 74 24.7 | Oct. 4. | 3.599 | .1659 | 13.39 | .6174 | do. | Bache-Fund M., D. C. 19. |
| | Hanover (north of observ'y). | 43 42.3 | 72 17.1 | 1879 | Oct. 6. | +10 50.5 | Oct. 6. | 74 55.8 | Oct. 6. | 3.478 | .1604 | 13.38 | .6169 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | (Station ¾ mile west). | 43 42.3 | 72 18.0 | 1879 | Oct. 7. | +11 38.4 | Oct. 7. | 75 02.7 | Oct. 7. | 3.473 | .1601 | 13.46 | .6204 | | |

## NEW JERSEY.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bergen Neck. | 40 45.8 | 74 02.6 | 1840 | July 18, Oct. 16. | + 5 53 | .......... | ..... | .......... | .... | .... | .... | .... | S. C. Rowan ? (F. R. Hassler). | Azim. Compass. |
| 2 | Mount Mitchell. | 40 24.5 | 74 00.4 | 1840 | Sept., Oct., Nov. | + 5 29 | .......... | ..... | .......... | .... | .... | .... | .... | S. C. Rowan (F. R. Hassler). | do. |
| 3 | Sandy Hook. | 40 27.7 | 74 00.2 | 1842 | Sept. | + 5 32.5 | .......... | ..... | .......... | .... | .... | .... | .... | Direction of F. R. Hassler. | do. |
| | do. | 40 27.7 | 74 00.2 | 1844 | Jan. | + 5 51.1 | .......... | ..... | .......... | .... | .... | .... | .... | G. M. Bache, J. Hall | Azim. Comp. ? |
| | Mount Mitchell. | 40 24.5 | 74 00.4 | 1844 | do. | + 5 39.4 | .......... | ..... | .......... | ... | .... | .... | .... | do. | do. |
| | Sandy Hook. | 40 27.7 | 74 00.2 | 1844 | Aug. 20, 22. | + 5 51.0 | Aug. | 72 37.9 | Aug. | 4.077 | .1880 | 13.66 | .6298 | J. Renwick. | Tr. & Simms Var. Tran. of Colum. Col., Rob. D. C. of Gir. Col. |
| 4 | Newark. | 40 44.8 | 74 10.0 | 1846 | May 14. | + 5 35.1 | May 16. | 72 52.2 | May 16. | 3.964 | .1828 | 13.46 | .6206 | John Locke. | M. 2, Robinson D. Comp. |
| 5 | White Hill. | 40 08.3 | 74 43.9 | 1846 | May 20. | + 4 25.9 | May 20. | 72 06.2 | May 20. | 4.147 | .1912 | 13.50 | .6222 | do. | do. |
| 6 | Church Landing. | 39 40.6 | 75 31.3 | 1846 | June 6. | + 5 49.1 | June 6. | 71 22.0 | June 6. | 4.311 | .1988 | 13.49 | .6222 | do. | do. |
| 7 | Pine Mount. | 39 25.0 | 75 20.3 | 1846 | June 19. | + 3 14.2 | June 19. | 71 41.4 | June 19. | 4.237 | .1954 | 13.49 | .6220 | do. | do. |
| 8 | Hawkins. | 39 25.6 | 75 17.3 | 1846 | June 20. | + 2 58.8 | June 20. | 71 42.6 | June 20. | 4.224 | .1948 | 13.46 | .6209 | do. | do. |
| 9 | Port Norris. | 39 14.6 | 75 01.3 | 1846 | June 23. | + 3 04.4 | June 23. | 71 39.6 | June 23. | 4.211 | .1942 | 13.38 | .6172 | do. | do. |
| 10 | Egg Island Light-House. | 39 10.5 | 75 08.4 | 1846 | June 25. | + 3 03.0 | June 25. | 71 45.1 | June 25. | 4.206 | .1939 | 13.43 | .6192 | do. | do. |
| 11 | Cape May Light-House. | 38 55.8 | 74 58.0 | 1846 | June 28. | + 3 05.1 | June 29. | 71 25.8 | June 29. | 4.255 | .1962 | 13.36 | .6161 | do. | do. |
| 12 | Townbank. | 38 58.6 | 74 57.7 | 1846 | June 30. | + 2 59.0 | June 30. | 71 23.6 | June 30. | 4.269 | .1968 | 13.38 | .6168 | do. | do. |
| 13 | Pilottown. | 38 47.1 | 75 09.5 | 1846 | July 2, 3. | + 2 42.7 | July 2. | 71 18.5 | July 2. | 4.290 | .1978 | 13.39 | .6172 | do. | do. |
| 14 | Chew. | 39 48.2 | 75 10.1 | 1846 | July 15. | + 3 45.2 | July 14, 15. | 72 14.4 | July 15. | 4.105 | .1893 | 13.46 | .6206 | do. | do. |
| 15 | Tuckerton. | 39 36.1 | 74 19.8 | 1846 | ............ | ..... | Nov. 7. | 72 12.3 | Nov. 9. | 4.063 | .1873 | 13.30 | .6129 | T. J. Lee. | M. 1, Rob. D. C. |
| 16 | Old Inlet. | 39 30.8 | 74 17.2 | 1846 | Nov. 10. | + 4 27.8 | .......... | ..... | .......... | .... | .... | .... | .... | do. | M. 1. |
| 17 | Mount Rose. | 40 22.2 | 74 43.3 | 1852 | Aug. 13, 14, 15. | + 5 31.8 | Aug. 12, 14. | 72 42.5 | Aug. 13, 14, 18. | 4.130 | .1904 | 13.90 | .6406 | J. E. Hilgard. | M. 2, Barrow D, C. of Sm'n Inst. |
| | Cape May Light-House. | 38 55.8 | 74 58.0 | 1855 | Aug. 3. | + 3 45.4 | Aug. 3. | 71 34.4 | Aug. 3. | 4.182 | .1928 | 13.23 | .6100 | C. A. Schott. | Sm'n Inst. M., Gambey D. C. |
| | Sandy Hook. | 40 27.7 | 74 00.3 | 1855 | Aug. 14. | + 6 11.2 | Aug. 14. | 72 52.0 | Aug. 14. | 3.917 | .1806 | 13.30 | .6130 | do. | do. |
| 18 | Atlantic City. | 39 21.8 | 74 24.9 | 1860 | Aug. 22, 23. | + 4 54.0 | Aug. 22, 23. | 71 47.0 | Aug. 22, 23. | 4.205 | .1939 | 13.45 | .6203 | do. | M. 6, D. C. 9. |
| 19 | Barnegat Light-House. | 39 45.8 | 74 06.4 | 1860 | Aug. 25, 26. | + 5 24.0 | Aug. 26. | 72 05.3 | Aug. 25, 26. | 4.108 | .1894 | 13.36 | .6159 | do. | do. |
| 20 | Long Beach. | 39 32.0 | 74 15.6 | 1860 | Aug. 27, 28. | + 5 18.5 | Aug. 24, 28. | 71 58.5 | Aug. 27, 28. | 4.156 | .1916 | 13.43 | .6192 | do | do. |
| | Sandy Hook. | 40 27.7 | 74 00.2 | 1873 | Nov. 5, 6, 7, 9. | + 7 09.0 | Nov. 8, 9. | 72 29.6 | Nov. 5, 6, 7, 9. | 4.040 | .1863 | 13.43 | .6193 | T. C. Hilgard. | Th. M. 7, D. C. 10. |
| | Cape May Light-House. | 38 55.8 | 74 58.0 | 1874 | June 25. | + 4 37.8 | June 27. | 71 28.5 | June 27. | 4.283 | .1975 | 13.48 | .6216 | do. | Bache-Fund M., D. C. 19. |
| | Sandy Hook. | 40 27.7 | 74 00.2 | 1879 | July 17, 18. | + 7 32.0 | July 17, 18. | 72 08.3 | July 17, 18. | 4.078 | .1880 | 13.30 | .6130 | J. B. Baylor. | Th. M. 9, D. C. 18. |

## TABLES OF MAGNETIC RESULTS—Continued.

### NEW YORK.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Buttermilk. | 41 06.6 | 73 48.6 | 1833 | June 10 to 30. | + 3 56 | ............ | ...... | ............ | ... | .... | .... | .... | Direction of F. R. Hassler. | Azim. Comp. |
| 2 | Round Hill. | 41 06.2 | 73 40.4 | 1833 | July 2 to 18. | + 5 43 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 3 | Bald Hill. | 41 12.8 | 73 28.7 | 1833 | July 22, 23. | + 5 34 | ............ | ...... | ............ | .... | ... | .... | .... | do. | do. |
| 4 | Howard. | 40 37.6 | 74 05.4 | 1840 | June 16 to July 11 | + 5 01 | ............ | ...... | ............ | .... | .... | .... | .... | S. C. Rowan? (F. R. Hassler). | do. |
| 5 | New York, Columbia College (old site). | 40 42.6 | 74 00.5 | 1844 | Aug. 24. | + 6 13.1 | Aug. 8, 13, 31. | 72 37.8 | August. | 4.071 | .1877 | 13.64 | .6287 | J. Renwick. | M. 2, Robinson D.C. of Gir. Col. |
| 6 | New Rochelle. | 40 52.5 | 73 47.3 | 1844 | Sept. 10. | + 5 29.5 | Sept. 10. | 72 44.0 | Sept. 10. | 3.845 | .1773 | 12.95 | .5973 | do. | do. |
| 7 | Port Chester. | 40 59.6 | 73 39.7 | 1844 | Sept. 11. | + 5 58.0 | Sept. 11. | 72 53.4 | ............ | .... | .... | .... | .... | do. | Tr. & Simms, Var. Tran. of Colum. Col., Rob. D.C. of Gir. Col. |
| 8 | Manhattanville, Bloomingdale | 40 50.3 | 73 56.4 | 1844 | ... .......... | ...... | Sept. 3. | 72 49.5 | Sept. 3. | 4.008 | .1848 | 13.57 | .6258 | J. Renwick, Lieut. Lefroy. | M. 2, Rob. D. C. of Gir. Col. |
| 9 | Lloyd Harbor, Huntington. | 40 55.6 | 73 25.1 | 1844 | Sept. 15. | + 6 11.6 | Sept. 15. | 72 50.6 | Sept. 15. | 3.857 | .1778 | 13.08 | .6027 | J. Renwick. | Tr. & Simms, Var. Tran. of Colum. Col., Rob. D.C. of Gir. Col. |
| 10 | Oyster Bay. | 40 52.3 | 73 31.6 | 1844 | Sept. 16. | + 6 50.5 | Sept. 16, 17. | 72 58.5 | Sept. 16, 17. | 3.894 | .1795 | 13.30 | .6131 | do. | M. 2, Rob. D. C. of Gir. Col. |
| 11 | Greenport. | 41 06 | 72 21 | 1845 | Aug. 19. | + 7 14.4 | Aug. 19. | 72 57.9 | Aug. 19. | 3.850 | .1775 | 13.14 | .6059 | do. | M. 2, Rob. & Bar. D. C. |
| | New York. | 40 42.6 | 74 00.5 | 1845 | Sept. 4. | + 6 25.3 | Sept. 4. | 72 40.6 | ... ........ | .... | .... | .... | ... | do. | do. |
| 12 | Drowned Meadow. | 40 56.1 | 73 03.8 | 1845 | Sept. 11. | + 6 03.6 | .......... | .. .. | ............ | .... | .... | ... | .... | do. | M. 2. |
| 13 | Sands' Point. | 40 51.9 | 73 43.8 | 1845 | Sept. 26. | + 7 14.6 | ..... ...... | ...... | . .......... | ... | .... | ... | .... | do. | do. |
| | Bloomingdale. | 40 50.3 | 73 56.4 | 1846 | Apr. 30. | + 5 09.7 | Apr. 27, 30. | 72 39.0 | Apr. 27, 30. | 4.009 | .1848 | 13.44 | .6197 | John Locke. | M. 2, Robinson D. Comp. |
| 14 | Flatbush or Mount Prospect, Brooklyn. | 40 40.3 | 73 58.0 | 1846 | May 6. | + 5 54.7 | May 6. | 72 27.6 | May 6. | 4.054 | .1869 | 13.45 | .6202 | do. | do. |
| 15 | Cole, Staten Island. | 40 31.9 | 74 14.1 | 1846 | May 7. | + 5 37.4 | May 11. | 72 34.2 | May 11. | 4.028 | .1857 | 13.45 | .6200 | do. | do. |
| | Sands' Point. | 40 51.9 | 73 43.8 | 1847 | Oct. 8, 9, 10, 11. | + 6 09.9 | ............ | ...... | ... ........ | .... | ... | .... | ... | R. H. Fauntleroy. | M. 2. |
| 16 | Legget. | 40 48.9 | 73 53.5 | 1847 | Oct. 16, 17, 18, 19, 20. | + 5 41.0 | Oct. 15, 16, 18. | 72 52.7 | Oct. 16, 18, 20. | 3.976 | .1833 | 13.51 | .6226 | do. | M. 2, Rob. & Bar. D. C. |
| 17 | Fire Island Light-House. | 40 37.9 | 73 13.2 | 1848 | .............. | ..... | ............ | ...... | July 15. | 3.932 | .1813 | .... | .... | J. S. Ruth. | M. 1. |
| 18 | New York, Governor's Island. | 40 41.5 | 74 01.1 | 1855 | Aug. 7. | + 6 39.6 | Aug. 7. | 72 46.3 | Aug. 7. | 3.926 | .1810 | 13.25 | .6111 | C. A. Schott. | Sm'n Inst'n M., Gam. D. C. |
| 19 | New York, Bedloe's Island. | 40 41.4 | 74 02.7 | 1855 | Aug. 8. | + 7 02.1 | Aug. 8. | 72 59.2 | Aug. 8. | 3.920 | .1807 | 13.40 | .6176 | do. | do. |
| 20 | New York, receiving reservoir | 40 46.7 | 73 58.2 | 1855 | Aug. 11. | + 6 28.0 | Aug. 10. | 72 44.4 | Aug. 10. | 3.938 | .1816 | 13.27 | .6120 | do. | do. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21 | Greenbush. | 42 37.5 | 73 44.3 | 1855 | Aug. 31. | + 7 54.7 | Aug. 31. | 75 11.1 | Aug. 31. | 3.587 | .1654 | 14.03 | .6469 | do. | do. |
| 22 | Coldspring. | 41 25.0 | 73 57.6 | 1855 | Sept. 1. | + 5 34.0? | Sept. 1. | 73 54.8 | Sept. 1. | 3.790 | .1747 | 13.68 | .6305 | do. | do. |
| 23 | Albany, Dudley Observatory. | 42 39.8 | 73 45.0 | 1858 | May 12, 13, 14. | + 8 17.0 | May 13, 14, 19. | 74 55.6 | May 15, 17. | 3.586 | .1653 | 13.79 | .6356 | G. W. Dean. | M. 1. |
| 24 | Fire Island. | 40 37.8 | 73 12.9 | 1860 | Sept. 1, 2. | + 7 45.7 | Sept. 1, 2. | 73 00.2 | Sept. 1, 2. | 3.900 | .1798 | 13.34 | .6151 | C. A. Schott. | M. 6, D. C. 9 |
| 25 | Sag Harbor. | 40 59.9 | 72 17.4 | 1860 | Sept. 4, 5. | + 8 27.7 | Sept. 4, 5. | 73 20.9 | Sept. 4, 5. | 3.903 | .1800 | 13.62 | .6282 | do. | do. |
| | Mount Prospect. | 40 40.3 | 73 58.0 | 1860 | Sept. 21, 22. | + 6 44.0 | Sept. 20, 21, 22. | 72 40.8 | Sept. 20, 21, 22. | 4.052 | .1868 | 13.61 | .6275 | do. | do. |
| 26 | Bath. | 42 20.8 | 77 21.3 | 1862 | Aug. 11. | + 4 47.9 | Aug. 11. | 74 26.2 | Aug. 11. | 3.671 | .1693 | 13.68 | .6308 | do. | M. 3, D. C. 8. |
| 27 | Ruland. | 40 50.7 | 73 02.0 | 1865 | May 25, 26, 27. | + 7 30.8 | May 25, 26, June 6. | 72 54.9 | May 29, 30. | 3.945 | .1819 | 13.43 | .6191 | E. Goodfellow (A. D. Bache). | M. 1, D. C. 4. |
| 28 | West Hills. | 40 48.9 | 73 25.5 | 1865 | Aug. 14, 16, 17. | + 7 01.5 | Aug. 10, 11, 12, 14 | 72 56.8 | Aug. 18, 19, 21. | 3.930 | .1812 | 13.40 | .6179 | do. | do. |
| | New York, Central Park. | 40 46.2 | 73 58.2 | 1872 | Oct. 31, Nov. 1, 2 | + 8 45.8? | Nov. 1, 2, 4. | 72 35.8 | Nov. 1, 2. | 3.982 | .1836 | 13.31 | .6138 | A. H. Scott (E. Goodfellow). | M. 6, D. C. 4. |
| 29 | Carpenter's Point, Port Jervis. | 41 21.4 | 74 41.7 | 1873 | June 19, 20, 21. | + 7 04.8 | June 21. | 73 14.3 | June 23. | 3.897 | .1797 | 13.51 | .6231 | E. Smith. | M. 6. D. C. 8. |
| 30 | Duer. | 40 59.8 | 73 54.2 | 1873 | August. | + 7 37 | .......... | ...... | ............ | .... | .... | .... | .... | G. H. Cook. | Surv.'s Comp. |
| | New York, Central Park. | 40 46.2 | 73 58.2 | 1873 | Dec. 16, 17. | + 9 07.1* | ............ | ...... | ............ | .... | .... | .... | .... | T. C. Hilgard. | Th. M. 7. |
| | do. | 40 47.6 | 73 57.3 | 1874 | Jan. 24. | + 9 18.4* | ............ | ... | ............ | .... | .... | .... | .... | do. | do. |
| 31 | Oxford. | 42 26.5 | 75 40.5 | 1874 | May 29, 30, June 2, 3, 4, 5, 6. | + 6 55.7 | June 4. | 74 05.8 | June 4. | 3.726 | .1718 | 13.60 | .6270 | do. | Bache-Fund M., D. C. 19. |
| 32 | Ithaca. | 42 27.5 | 76 33.0 | 1874 | June 13. | + 5 25.8 | June 13. | 74 14.7 | June 13. | 3.664 | .1689 | 13.49 | .6221 | do. | do. |
| 33 | Potsdam. | 44 37.0 | 75 00.0 | 1874 | Oct. 15. | + 9 25.1 | Oct. 15. | 76 03.3 | Oct. 15. | 3.268 | .1507 | 13.56 | .6253 | do. | do. |
| 34 | Pierrepont Manor. | 43 44.5 | 76 04.0 | 1874 | Oct. 20. | + 6 11.9 | Oct. 20. | 75 25.1 | Oct. 20. | 3.470 | .1600 | 13.78 | .6355 | do. | do. |
| 35 | Clinton, Hamilton College. | 43 03.2 | 75 24.2 | 1874 | Oct. 25. | + 8 05.5 | Oct. 25. | 74 37.5 | Oct. 25. | 3.635 | .1676 | 13.71 | .6321 | do. | do. |
| 36 | Patchogue. | 40 44.9 | 73 01.5 | 1875 | July 30, 31, Aug. 4. | + 8 00.5 | Aug. 4, 5. | 72 45.4 | July 30, 31, Aug. 4. | 3.968 | .1830 | 13.39 | .6173 | J. M. Poole. | do. |
| 37 | Far Rockaway. | 40 35.7 | 73 46.0 | 1875 | Aug. 6. | + 7 12 | ............ | ...... | ............ | .... | ... | .... | .... | do. | Bache-Fund M. |
| 38 | Babylon. | 40 41.5 | 73 19.5 | 1875 | Aug. 13, 14. | + 7 35 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 39 | West Hampton. | 40 51.0 | 72 34.0 | 1875 | Aug. 19, 20. | + 8 40 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
| 40 | East Hampton. | 40 57.5 | 72 11.5 | 1875 | Aug. 21, 23, 24. | + 9 05.6 | Aug. 24. | 72 47.3 | Aug. 23, 24. | 3.986 | .1838 | 13.47 | .6212 | do. | Bache-Fund M., D. C. 19. |
| 41 | Montauk Point. | 41 04.2 | 71 51.0 | 1875 | Aug. 27. | + 9 45 | ............ | ...... | ............ | .... | .... | .... | .... | do. | Bache-Fund M. |
| 42 | Sherburne. | 42 41.2 | 75 33.0 | 1875 | Aug. 31, Sept. 1. | + 7 49.5 | Sept. 3, 4. | 74 15.1 | Sept. 2, 3, 4. | 3.726 | .1718 | 13.73 | .6330 | do. | Bache-Fund M., D. C. 19. |
| 43 | Rouse's Point. | 45 00.4 | 73 21.2 | 1879 | Oct. 1. | +13 39.1 | Oct. 1. | 76 18.2 | Oct. 1. | 3.270 | .1508 | 13.81 | .6369 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | Albany. | 42 39.8 | 73 45.1 | 1879 | Oct. 21, 24. | + 9 51.7 | Oct. 21, 24. | 74 18.9 | Oct. 21, 24. | 3.645 | .1681 | 13.48 | .6218 | do. | do. |

NORTH CAROLINA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Bodie's Island. | 35 47.5 | 75 32.0 | 1846 | Dec. 26, 27, 28. | + 1 13.4 | Dec. 26, 27, 28. | 68 18.1 | Dec. 25, 27. | 4.755 | .2192 | 12.86 | .5929 | C. O. Boutelle. | M. 1, Dip-Needle C. 6. |
| 2 | Stevenson's Point. | 36 06.3 | 76 11.4 | 1847 | Jan. 30, 31, Feb. 1 to 15. | + 1 39.6 | Feb. 8, 12, 13. | 68 54.5 | Jan. 30, Feb. 6, 15. | 4.660 | .2149 | 12.95 | .5972 | do. | do. |
| 3 | Shellbank. | 36 03.6 | 75 44.5 | 1847 | Mar. 22 to 26, 28 to 31, Apr. 1 to 8. | + 1 44.8 | Apr. 8, 9. | 68 37.8 | Mar. 26, Apr. 1, 7. | 4.714 | .2174 | 12.94 | .5966 | C. O. Boutelle, G. Davidson. | do. |
| 4 | Raleigh. | 35 46.8 | 78 38.1 | 1854 | Jan. 7, 8, 9, 10, 11. | − 0 44.5 | Jan. 7, 9, 10, 16 | 68 11.6 | Jan. 13, 14. | 4.963 | .2288 | 13.36 | .6159 | G. W. Dean. | M. 1, D. C. 4. |

*Supposed local deflection.

## TABLES OF MAGNETIC RESULTS—Continued.

### NORTH CAROLINA—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
| 5 | Wilmington. | 34 14.0 | 77 56.6 | 1854 | May 30, 31, June 1, 2. | − 1 13.5 | June 3, 5. | 66 47.2 | June 3, 5. | 5.195 | .2395 | 13.18 | .6076 | G. W. Dean. | M. 1, D. C. 4. |
| 6 | Fort Johnson, Smithville. | 33 55.0 | 78 00.9 | 1859 | May 3, 4, 5. | − 0 38.1 | May 3, 4, 5. | 66 17.1 | May 6, 7. | 5.260 | .2425 | 13.08 | .6030 | do. | do. |
| 7 | Portsmouth Island. | 35 04.0 | 76 03.2 | 1871 | Apr. 1. | + 2 22.0 | Apr. 1, 5. | 67 13.6 | Apr. 3, 5. | 5.006 | .2308 | 12.93 | .5963 | A. T. Mosman. | M. 3, D. 8. |
| 8 | New Berne. | 35 07.4 | 77 03.3 | 1874 | Dec. 21, 23, 24. | + 1 20.4 | Dec. 22, 24. | 67 30.6 | Dec. 21, 23, 24. | 4.959 | .2286 | 12.96 | .5976 | J. B. Baylor. | Bache-Fund M., D. C. 19. |
|  | Fort Johnson. | 33 55.0 | 78 00.9 | 1874 | Dec. 27, 28, 29, 30. | + 0 23.9 | Dec. 29, 30. | 66 00.6 | Dec. 27, 28, 29, 30. | 5.297 | .2442 | 13.03 | .6006 | do. | do. |
| 9 | Sand Island. | 35 50.4 | 75 40.1 | 1876 | Jan. 21, 22, Feb. 9. | + 2 58.9 | Feb. 7. | 68 05.4 | Jan. 22. | 4.893 | .2256 | 13.11 | .6046 | E. Smith. | Bache-Fund M., D. C. 18. |
| 10 | Beaufort. | 34 43 | 76 40 | 1880 | Jan. 13, 14, 15. | + 1 44.1 | Jan. 14, 15. | 66 49.8 | Jan. 14, 15. | 5.055 | .2331 | 12.85 | .5924 | J. B. Baylor. | Th. M. 9, D. C. 18. |

### OHIO.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
| 1 | South Point. | 38 25.2 | 82 35.4 | 1864 | Feb. 19. | − 1 52.9 | ............ | ...... | ............ | .... | .... | .... | .... | A. T. Mosman. | M. 1. |
| 2 | Columbus. | 39 57.7 | 82 59.7 | 1871 | Oct. 4, 5, 6. | − 1 20.6 | Oct. 3 to 9. | 71 09.8 | Oct. 7. | 4.369 | .2014 | 13.53 | .6238 | do. | M. 1, D. C. 4. |
| 3 | Cleveland. | 41 30.5 | 81 41.5 | 1871 | Nov. 9, 10, 11. | + 0 32.6 | Nov. 6, 7, 8, 9. | 73 09.3 | Nov. 13, 14. | 4.000 | .1844 | 13.80 | .6364 | E. Goodfellow. | do. |
|  | do. | 41 30.5 | 81 41.5 | 1880 | July 9, 10, 12. | + 1 38.5 | July 10, 12. | 73 02.4 | July 9, 10, 12. | 3.996 | .1842 | 13.70 | .6315 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 4 | Cincinnati. | 39 08.6 | 84 25.4 | 1880 | Nov. 27, 29, 30. | − 2 14.4 | Ncv. 29, 30. | 70 24.7 | Nov. 29, 30. | 4.488 | .2069 | 13.39 | .6171 | do. | do. |
| 5 | Athens. | 39 19.8 | 82 02 | 1880 | Dec. 3, 4. | − 0 40.5 | Dec. 3. | 70 58.7 | Dec. 3, 4. | 4.390 | .2024 | 13.47 | .6210 | do. | do. |

### OREGON.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
| 1 | Ewing Harbor. | 42 44.4 | 124 30.3 | 1851 | Nov. 19 to 29; 11 days. | −18 29.7 | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Th. M. III. |
| 2 | Koos Bay. | 43 23.9 | 124 17 | 1863 | July (?). | −18 37 | ............ | ...... | ............ | .... | .... | .... | .... | J. S. Lawson. | Surv.'s Comp. ? |
| 3 | Astoria. | 46 11.3 | 123 50.3 | 1870 | Aug. 13, 15. | −23 10 ? | ............ | ...... | ............ | .... | .... | .... | .... | G. Davidson. | Th. M. 5. |
| 4 | Portland. | 45 31.2 | 122 41.0 | 1870 | Aug. 19, 23. | −22 21 | ............ | ...... | ............ | .... | .... | .... | .... | do. | do. |
|  | do. | 45 31.5 | 122 40.5 | 1880 | Apr. 30. | −22 53 | May 1. | 69 35.6 | May 1. | 4.414 | .2035 | 12.66 | .5836 | W. H. Dall, M. Baker. | Magc. Theod. 123, D. C. 21. |
| 5 | Jacksonville. | 42 18 | 122 58 | 1881 | July 16, 17. | −17 24.4 | July 16. | 66 03.2 | July 16, 17. | 5.021 | .2315 | 12.37 | .5704 | J. S. Lawson. | Th. M. 8, D. C. 21. |
| 6 | Canyonville. | 42 54 | 123 18 | 1881 | July 19, 20. | −17 48.5 | July 19. | 65 57.9 | July 19. | .... | .... | .... | .... | do. | do. |
| 7 | Oakland. | 43 26 | 123 18 | 1881 | July 22. | −19 41.2 | July 22. | 66 59.4 | July 22. | .... | .... | .... | .... | do. | do. |
| 8 | Eugene. | 44 03 | 123 00 | 1881 | July 24, 25. | −20 48.1 | July 25. | 67 51.0 | July 25. | 4.796 | .2211 | 12.72 | .5864 | do. | do. |
| 9 | Albany. | 44 39 | 123 02 | 1881 | July 28. | −21 42.0 | July 28. | 68 08.5 | July 27, 28. | 4.715 | .2174 | 12.66 | .5839 | do. | do. |
| 10 | Salem. | 44 56.5 | 122 58 | 1881 | July 31, Aug. 1. | −19 58.0 | July 31. | 68 13.3 | July 30. | 4.702 | .2168 | 12.67 | .5843 | do. | do. |

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Portland. | 45 31.5 | 122 41.5 | 1881 | Aug. 4, 5, 6. | −22 12.0 | Aug. 6. | 69 24.2 | Aug. 5, 6. | 4.488 | .2069 | 12.76 | .5882 | do. | do. |
| | Astoria. | 46 11.5 | 123 50 | 1881 | Aug. 10, 11. | −22 26.4 | Aug. 11. | 69 13.4 | Aug. 10, 11. | 4.508 | .2079 | 12.71 | .5861 | do. | do. |
| 11 | Saint Helen's. | 45 52.3 | 122 48.1 | 1881 | Aug. 13, 14, 15. | −19 08.0 | Aug. 15. | 70 54.1 | Aug. 15. | 4.350 | .2006 | 13.29 | .6131 | do. | do. |
| 12 | Umatilla. | 45 57 | 119 20 | 1881 | Oct. 4, 5. | −21 32.2 | Oct. 5. | 70 10.2 | Oct. 5. | 4.421 | .2038 | 13.03 | .6008 | do. | do. |
| 13 | Blalock. | 45 44 | 120 15 | 1881 | Oct. 7, 8. | −20 21.2 | ... ........ | ...... | Oct. 8. | 4.495 | .2073 | ... | .... | do. | Th. M. 8. |
| 14 | Three Mile Creek. | 45 39 | 120 58 | 1881 | Oct. 13, 14. | −21 02.8 | . ......... | ...... | Oct. 13, 14. | 4.473 | .2062 | .... | .... | do. | do. |

## PENNSYLVANIA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Girard College, Philadelphia. | 39 58.4 | 75 10.2 | 1846 | May 23. | + 3 51.1 | May 23. | 72 01.0 | May 23. | 4.143 | .1910 | 13.42 | .6187 | John Locke. | M. 2, Robinson D. Comp. |
| 2 | Bristol, Vanuxen. | 40 06.7 | 74 53.0 | 1846 | July 10, 11. | + 4 27.8 | June 10, 11, 12 | 72 22.3 | July 10, 11, 12. | 4.068 | .1876 | 13.43 | .6195 | do. | do. |
| 3 | Yard. | 39 58.3 | 75 23.1 | 1854 | Oct. 26, 27, 28. | + 6 42.3 | Nov. 3. | 73 01.2 | Oct. 28. | 3.876 | .1787 | 13.27 | .6120 | J. E. Hilgard. | M. 2, Barrow D. C. of Sm'n Inst. |
| | Girard College. | 39 58.4 | 75 10.2 | 1855 | Sept. 5. | + 4 31.7 | Sept. 5. | 72 17.7 | Sept. 5. | 4.226 | .1949 | 13.90 | .6409 | C. A. Schott. | Sm'n Inst. M. Gambey D. C. |
| 4 | Harrisburg. | 40 15.8 | 76 52.9 | 1862 | July 28, 29. | + 3 44.5 | July 29. | 72 31.6 | July 28, 29. | 4.048 | .1866 | 13.48 | .6216 | do. | M. 3, D. C. 8. |
| 5 | Johnson's Tavern, near Brownsville. | 39 59.5 | 79 48.1 | 1862 | July 31. | + 1 13.6 | July 31. | 71 57.0 | July 31. | 4.173 | .1924 | 13.47 | .6209 | do. | do. |
| 6 | Erie. | 42 07.5 | 80 06.3 | 1862 | Aug. 6, 7. | + 1 33.0 | Aug. 7. | 73 52.3 | Aug. 6, 7. | 3.761 | .1734 | 13.54 | .6242 | do. | do. |
| 7 | Williamsport. | 41 14.0 | 77 02.4 | 1862 | Aug. 13. | + 4 25.7 | Aug. 13. | 72 51.0 | Aug. 13. | 3.958 | .1825 | 13.42 | .6189 | do. | do. |
| | Girard College. | 39 58.4 | 75 10.2 | 1862 | Aug. 15, 16. | + 5 00.0 | Aug. 15, 16. | 72 05.8 | Aug. 15, 16. | 4.124 | .1901 | 13.42 | .6185 | do. | do. |
| | do. | 39 58.4 | 75 10.2 | 1872 | Oct. 19, 20, 21. | + 5 27.8 | Oct. 19, 20. | 72 15.4 | Oct. 21, 22. | 4.161 | .1919 | 13.65 | .6297 | A. H. Scott (E. Goodfellow). | M. 6, D. C. 4. |
| 8 | Bethlehem. | 40 37.5 | 75 18.0 | 1874 | June 20. | + 5 19.5 | June 20. | 73 38.9 | June 20. | 3.839 | .1770 | 13.64 | .6287 | T. C. Hilgard. | Bache-Fund M., D. C. 19. |
| | Harrisburg. | 40 15.8 | 76 52.9 | 1877 | Sept. 25, 26. | + 4 53.5 | Sept. 27. | 72 20.5 | Sept. 27. | 4.123 | .1901 | 13.59 | .6267 | E. Smith, J. B. Baylor. | do. |
| | Girard College. | 39 58.3 | 75 10.3 | 1877 | Oct. 2, 3, 5, 6. | + 6 02.2 | Oct. 2, 3, 6. | 71 41.3 | Oct. 3, 5, 6. | 4.211 | .1942 | 13.40 | .6181 | J. B. Baylor. | do. |

## RHODE ISLAND.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | McSparran. | 41 29.7 | 71 27.4 | 1844 | July 10 to 24; 12 days. | + 8 48.5 | July 13, 18, 22, 23, 24. | 73 47.6 | ............ | .... | .... | ... | .... | A. D. Bache, T. J. Lee. | Gam. Decl'n Tr. Gir. Col., Fox Dip-Needle. |
| 2 | Spencer. | 41 40.7 | 71 29.7 | 1844 | July 29 to Aug. 31; 16 days. | + 9 05.9 | July 30, Aug. 13, 25, Sept. 2. | 75 07.1 | ............ | .... | .... | .... | .... | T. J. Lee. | do. |
| 3 | Beaconpole. | 41 59.7 | 71 27.0 | 1844 | Oct. 31 to Nov. 18; 9 days. | + 9 27.0 | Nov. 8, 16, 18, 19. | 74 21.9 | ............ | .... | .... | .... | .... | do. | Gam. Decl'n Tr. Gir. Col., Robinson D. C. |
| 4 | Point Judith. | 41 21.6 | 71 28.9 | 1847 | Sept. 5, 6, 8, 9. | + 8 59.7 | Sept. 11, 12, 13, 14. | 73 45.1 | Sept. 6, 7, 8. | 3.788 | .1747 | 13.54 | .6244 | R. H. Fauntleroy. | M. 2, Rob. and Bar. D. C. |
| 5 | Watch Hill. | 41 18.8 | 71 51.3 | 1847 | Sept. 17, 18, 19. | + 7 33.4 | ............ | ...... | ............ | .... | .... | ... | .... | do. | M. 2. |
| 6 | Providence. | 41 49.5 | 71 23.9 | 1855 | Aug. 20. | + 9 31.5 | Aug. 20. | 74 15.9 | Aug. 20. | 3.590 | .1655 | 13.24 | .6103 | C. A. Schott. | Sm'n Inst. M., Gam. D. C. |

## TABLES OF MAGNETIC RESULTS—Continued.

### SOUTH CAROLINA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Breach Inlet, near Charleston. | 32 46.3 | 79 48.9 | 1849 | Apr. 1 to 22; 14 days. | – 2 16.5 | Apr. 25. | 64 31.9 | Apr. 6, 11. | 5.547 | .2558 | 12.90 | .5949 | C. O. Boutelle, J. Hewston, G. W. Dean. | M. 1, Bar. D. C. of Sm'n Inst. |
| 2 | East Base, Edisto Island. | 32 33.3 | 80 13.5 | 1850 | Apr. 2, 4, 5, 6, 7. | – 2 53.6 | Apr. 5, 6, 7. | 64 04.1 | Apr. 8, 9, 10, 11. | 5.623 | .2593 | 12.86 | .5930 | G. Davidson. | M. , Gambey D. C. |
| 3 | Allston, near Georgetown. | 33 21.6 | 79 16.6 | 1853 | Dec. 21, 22, 23, 24, 25, 26, 27. | – 2 06.5 | Dec. 26, 27. | 65 29.5 | Dec. 24, 26, 27. | 5.439 | .2508 | 13.11 | .6046 | C. O. Boutelle. | M. 1, D. C. 4. |
| 4 | Columbia. | 34 00.0 | 81 02.1 | 1854 | Feb. 19, 20, 21, 22, 23. | – 3 02.2 | Feb. 27, 28, Mar. 1. | 66 07.7 | Feb. 24, 25. | 5.296 | .2442 | 13.09 | .6034 | G. W. Dean. | do. |
| 5 | Port Royal. | 32 17.7 | 80 38.5 | 1859 | Jan. 31, Feb. 1, 2, 3, 4, 5. | – 3 04.1 | Jan. 28, 29, 30. | 64 07.5 | ………… | …. | …. | …. | …. | C. O. Boutelle. | M. 6, D. C. 9. |
| 6 | Graham. | 32 13.3 | 80 45.5 | 1870 | Mar. 4 to 24. | – 1 55.5 | Apr. 23, 24. | 63 28.1 | Mar. 11, 12. | 5.663 | .2611 | 12.68 | .5845 | do. | M. 3, D. C. 6. |
| 7 | Beaufort. | 32 26.0 | 80 40.5 | 1874 | Apr. 20 to 30. | – 1 57.5 | ………… | …… | Apr. 16 to 25. | 5.603 | .2583 | …. | …. | do. | Th. M. 8. |
| | Fort Marshall, near Breach Inlet. | 32 46.4 | 79 48.8 | 1874 | May 27, 28, 29. | – 0 58.2 | ………… | …… | May 27, 28. | 5.530 | .2550 | …. | …. | C. O. Boutelle, J. B. Boutelle. | do. |
| | Beaufort. | 32 26.0 | 80 40.5 | 1875 | Apr. 20 to 30, June 1 to 9. | – 1 58.3 | ………… | …… | Apr. 9, 10, 12. | 5.586 | .2576 | …. | …. | C. O. Boutelle. | do. |
| | Breach Inlet. | 32 46.4 | 79 48.8 | 1880 | Jan. 21, 22. | – 0 25.6 | Jan. 21, 22. | 64 13.7 | Jan. 21, 22. | 5.530 | .2550 | 12.72 | .5865 | J. B. Baylor. | Th. M. 9, D. C. 18. |

### TENNESSEE.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Clifton. | 35 23.3 | 88 01.1 | 1865 | Mar. 8. | – 5 48 | ………… | …… | ………… | …. | …. | …. | …. | A. T. Mosman. | Azim. Comp. |
| 2 | Johnsonville. | 36 03.8 | 87 59.7 | 1865 | Mar. 10. | – 5 50 | ………… | …… | ………… | …. | …. | …. | …. | do. | do. |
| 3 | Fort Henry. | 36 30.4 | 88 03.7 | 1865 | Mar. 11. | – 6 24 | ………… | …… | ………… | …. | …. | …. | …. | do. | do. |
| 4 | Nashville. | 36 09.7 | 86 47.6 | 1877 | Dec. 5, 6, 7. | – 5 14.9 | Dec. 5, 6, 7. | 67 18.9 | Dec. 5, 6, 7. | 5.110 | .2356 | 13.25 | .6109 | A. Braid. | Th. M. 9, D. C. 18. |
| 5 | Bristol. | 36 35.8 | 82 11 | 1881 | July 9, 11. | – 0 38.5 | July 9, 11, 13. | 68 01.0 | July 9, 11. | 4.891 | .2255 | 13.07 | .6024 | J. B. Baylor. | do. |
| 6 | Caryville. | 36 19 | 84 14 | 1881 | July 14, 15. | – 1 12.3 | July 14, 15. | 67 55.7 | July 14, 15. | 4.972 | .2292 | 13.23 | .6100 | do. | do. |
| 7 | Athens. | 35 27 | 84 37 | 1881 | July 20, 21. | – 1 44.2 | July 20, 21. | 66 11.7 | July 20, 21. | 5.290 | .2439 | 13.11 | .6043 | do. | do. |
| 8 | Chattanooga. | 35 00 | 85 18 | 1881 | July 28, 29. | – 2 26.1 | July 28, 29. | 66 09.7 | July 28, 29. | 5.307 | .2447 | 13.13 | .6054 | do. | do. |
| 9 | Tullahoma. | 35 22 | 86 13 | 1881 | Aug. 3, 4, 5. | – 3 30.9 | Aug. 3, 5. | 66 25.5 | Aug. 3, 5. | 5.215 | .2405 | 13.04 | .6013 | do. | do. |
| 10 | Murfreesboro'. | 35 53 | 86 25 | 1881 | Aug. 10, 11. | – 4 53.5 | Aug. 10, 11. | 66 53.3 | Aug. 10, 11. | 5.175 | .2386 | 13.18 | .6079 | do. | do. |
| 11 | Columbia. | 35 37 | 87 04 | 1881 | Aug. 17, 18. | – 4 35.5 | Aug. 17, 18. | 67 07.5 | Aug. 17, 18. | 5.140 | .2370 | 13.22 | .6097 | do. | do. |
| 12 | Pulaski. | 35 13 | 87 03 | 1881 | Aug. 24, 25. | – 5 01.5 | Aug. 23, 24. | 66 06.4 | Aug, 24, 25. | 5.251 | .2421 | 12.96 | .5977 | do. | do. |
| 13 | Grand Junction. | 35 05 | 89 13 | 1881 | Sept. 9, 10. | – 5 58.9 | Sept. 9, 10. | 66 00.4 | Sept. 9, 10. | 5.268 | .2429 | 12.96 | .5973 | do. | do. |
| 14 | Jackson. | 35 39 | 88 51 | 1881 | Sept. 16, 17. | – 5 49.8 | Sept. 16, 17. | 66 05.4 | Sept. 16, 17. | 5.272 | .2431 | 13.01 | .5998 | do. | do. |
| 15 | Rutherford. | 36 09 | 89 01 | 1881 | Sept. 20, 21. | – 5 59.6 | Sept. 20, 21. | 67 13.8 | Sept. 20, 21. | 5.118 | .2360 | 13.22 | .6097 | do. | do. |

## TEXAS.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Dollar Point. | 29 26.0 | 94 53.4 | 1848 | Apr. 24, 25, 26, 27, 28. | − 8 57.4 | Apr. 25, 26, 27, 28, May 1, 2. | 57 53.3 | May 5, 6, 8. | 6.541 | .3016 | 12.30 | .5674 | R. H. Fauntleroy. | M. 2, New Barrow D. C. |
| 2 | East Base, Galveston Island. | 29 12.9 | 94 55.8 | 1853 | Mar. 16, 17, 18, 19, 20, 21. | − 9 05.0 | Mar. 17, 18, 22. | 57 42.1 | Mar. 24, 25. | 6.524 | .3008 | 12.21 | .5630 | G. W. Dean. | M. 1, D. C. 4. |
| 3 | Jupiter. | 28 54.8 | 95 20.6 | 1853 | May 10, 11, 12, 13, 14, 15. | − 9 08.7 | May 10, 11, 12, 14. | 57 11.4 | May 16, 17. | 6.596 | .3041 | 12.18 | .5612 | do. | do. |
| 4 | Rio Grande, mouth. | 25 57.4 | 97 07.9 | 1853 | Nov. | − 9 00.9 | Nov. | 52 23.6 | ............ | ... | .... | .... | .... | W. H. Emory. | ........ |
| | Dollar Point. | 29 26.0 | 94 53.4 | 1868 | Feb. 24, 25. | − 8 42.9 | Feb. 24, 25, 26. | 58 04.1 | Feb. 24, 25, 26. | 6.443 | .2971 | 12.18 | .5617 | E. Goodfellow. | M. 1, D. C. 8. |
| 5 | Lavaca. | 28 37.6 | 96 37.3 | 1868 | Apr. 22, 23, 24. | − 9 05.2 | Apr. 22, 23, 24. | 57 11.2 | Apr. 21, 22, 23, 24. | 6.574 | .3031 | 12.13 | .5593 | do. | do. |
| 6 | Austin. | 30 16.4 | 97 44.2 | 1872 | Mar. 27, Apr. 5, 13, 15. | − 9 09 | ............ | ...... | ............ | .... | .... | .... | ... | W. Eimbeck. | Compasses. |
| | Dollar Point. | 29 25.9 | 94 53.4 | 1878 | May 29, 30, 31. | − 8 17.3 | June 3, 4. | 58 21.5 | May 30, 31, June 1. | 6.373 | .2938 | 12.15 | .5600 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 7 | San Antonio. | 29 25.4 | 98 29.3 | 1878 | June 10, 11, 12. | − 9 22.3 | June 11, 13. | 57 34.6 | June 10, 12. | 6.429 | .2964 | 11.99 | .5528 | do. | do. |
| | Austin. | 30 16.4 | 97 44.2 | 1878 | June 20, 21, 22. | − 8 57.5 | June 24, 25. | 58 56.7 | June 21, 22. | 6.269 | .2891 | 12.15 | .5604 | do. | do. |
| 8 | Hemstead. | 30 08.1 | 96 10 | 1878 | June 26. | − 8 36.7 | ............ | ... .. | ... ........ | .... | .... | .... | .... | do. | Comp. of Th. M. 9. |
| 9 | Groesbeck. | 31 33 | 96 30 | 1878 | June 28, July 1. | − 9 15.1 | ............ | ...... | ........ ... | .... | .... | .... | .... | do. | do. |
| 10 | Fort Worth. | 32 45.3 | 97 19.9 | 1878 | July 4, 5, 6. | − 9 39.9 | July 5, 8, 9. | 61 53.1 | July 4, 5, 8. | 5.921 | .2730 | 12.56 | .5793 | do. | Th. M. 9, D. C. 18. |
| 11 | Sherman. | 33 36 | 96 36 | 1878 | July 10, 11. | − 9 19.9 | ............ | ...... | ....... .... | .... | .... | .... | .... | do. | Comp. of Th. M. 9. |

## UTAH TERRITORY.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Salt Lake City. | 40 46.0 | 111 53.8 | 1869 | May 6 to 15. | −16 36.4 | May 17, 19. | 66 58.2 | May 6 to 15. | 5.044 | .2326 | 12.89 | .5946 | G. W. Dean, F. H. Agnew. | M. 1, D. C. 8. |
| 2 | Castle Rock. | 41 08 | 111 10 | 1878 | Oct. 18. | −16 57.1 | ....... .... | ..... | . ... .... | .... | .... | .... | .... | J. B. Baylor. | Comp. of Th. M. 9. |
| 3 | Ogden. | 41 13.5 | 111 59.9 | 1878 | Oct. 19, 21. | −17 16.4 | ....... .... | ...... | ............ | .... | .... | .... | .... | do. | do. |
| | Salt Lake City. | 40 46.0 | 111 53.8 | 1878 | Oct. 26, 28, 29. | −16 44.2 | Oct. 25, 28, 31. | 67 05.9 | Oct. 30, 31. | 4.987 | .2299 | 12.81 | .5908 | do. | Th. M. 9, D. C. 18. |
| 4 | Kelton. | 41 45.4 | 113 07.5 | 1881 | May 3, 4. | −17 45.5 | May 3, 4. | 67 49.7 | May 3, 4. | 4.865 | .2243 | 12.89 | .5944 | W. Eimbeck, R. A. Marr. | Th. M. 10, D. C. 15. |
| 5 | Corinne. | 41 33.2 | 112 06.0 | 1881 | May 5, 6, 7. | −17 30.9 | May 5, 6. | 67 47.8 | May 5, 6, 7. | 4.863 | .2242 | 12.87 | .5933 | do. | do. |
| | Salt Lake City. | 40 46.0 | 111 53.8 | 1881 | May 12, 13, 14. | −16 28.4 | May 12, 13. | 67 02.1 | May 13, 14. | 5.006 | .2308 | 12.83 | .5915 | do. | do. |

## VERMONT.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Burlington. | 44 29.3 | 73 13.4 | 1855 | Aug. 28. | + 9 57.1 | Aug. 28. | 75 56.8 | Aug. 28. | 3.425 | .1579 | 14.10 | .6503 | C. A. Schott. | Sm'n Inst. M., Gam. D. C. |
| 2 | Rutland. | 43 36 | 72 55 | 1859 | July 21. | + 9 49 | July 21. | 75 19.8 | July 21. | 3.464 | .1597 | 13.68 | .6306 | do. | M. 6. |
| | Burlington. | 44 28.2 | 73 12.3 | 1873 | Oct. 14, 15. | +11 19.0 | Oct. 13, 14, 15. | 75 24.2 | Oct. 14, 15. | 3.427 | .1580 | 13.60 | .6270 | T. C. Hilgard. | Th. M. 7, D. C. 10. |
| | Rutland. | 43 36.5 | 72 55.5 | 1873 | Oct. 17, 18. | +10 40.2 | Oct. 16, 17, 18. | 75 05.1 | Oct. 17, 18. | 3.492 | .1610 | 13.57 | .6255 | do. | do. |
| | do. | 43 36.5 | 72 55.5 | 1879 | Oct. 14, 15. | +11 09.0 | Oct. 14, 15. | 74 49.5 | Oct. 14, 15. | 3.550 | .1637 | 13.56 | .6253 | J. B. Baylor. | Th. M. 9, D. C. 18. |

## TABLE OF MAGNETIC RESULTS—Continued.

### VIRGINIA.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 1 | Petersburg. | 37 14.4 | 77 23.9 | 1852 | Aug. 9, 10, 11, 12, 13. | + 0 26.5 | Aug. 10, 11, 13. | 69 17.3 | Aug. 6, 7. | 4.640 | .2139 | 13.12 | .6048 | G. W. Dean (A. D. Bache). | M. 1, D. C. 4. |
| 2 | Snead. | 37 58.3 | 75 26.2 | 1856 | Sept. 2. | 2 18.4 | Sept. 2. | 70 31.0 | Sept. 2. | 4.448 | .2051 | 13.34 | .6150 | C. A. Schott. | M. 6, D. C. 5. |
| 3 | Joynes. | 37 41.7 | 75 36.9 | 1856 | Sept. 4. | 2 03.3 | Sept. 4. | 70 21.2 | Sept. 4. | 4.488 | .2069 | 13.35 | .6154 | do. | do. |
| 4 | Scott. | 37 20.5 | 75 54.1 | 1856 | Sept. 6. | 1 37.5 | Sept. 6. | 70 01.5 | Sept. 6. | 4.571 | .2108 | 13.38 | .6171 | do. | do. |
| 5 | Cape Charles. | 37 07.3 | 75 58.2 | 1856 | Sept. 7. | 1 35.2 | Sept. 7. | 69 43.3 | Sept. 7. | 4.622 | .2131 | 13.34 | .6149 | do. | do. |
| 6 | Old Point Comfort Light. | 37 00.0 | 76 18.4 | 1856 | Sept. 8. | 1 14.7 | Sept. 8. | 69 31.6 | Sept. 8. | 4.659 | .2148 | 13.32 | .6141 | do. | do. |
| 7 | Norfolk. | 36 51.4 | 76 17.5 | 1856 | Sept. 9. | 1 39.1 | Sept. 9. | 69 29.7 | Sept. 9. | 4.656 | .2147 | 13.29 | .6129 | do. | do. |
| 8 | do. | 36 50.5 | 76 17.1 | 1856 | Sept. 10. | 1 33.3 | Sept. 10. | 69 28.2 | Sept. 10. | 4.667 | .2152 | 13.31 | .6136 | do. | do. |
| 9 | Cape Henry Light-house. | 36 55.6 | 76 00.4 | 1856 | Sept. 11. | 1 27.9 | Sept. 11. | 69 39.0 | Sept. 11. | 4.623 | .2132 | 13.29 | .6131 | do. | do. |
| 10 | Fredericksburg. | 38 18.2 | 77 27.4 | 1856 | Sept. 17. | 1 02.3 | Sept. 17. | 70 37.9 | Sept. 17. | 4.449 | .2051 | 13.42 | .6184 | do. | do. |
| 11 | Richmond. | 37 31.7 | 77 26.0 | 1856 | Sept. 19. | 0 14.5 | Sept. 19. | 69 47.7 | Sept. 19. | 4.609 | .2125 | 13.34 | .6153 | do. | do. |
| 12 | Peach Grove. | 38 55.2 | 77 13.8 | 1869 | Nov. 1, 2, 3, 4, 5, 6. | 2 54.7? | Nov. 9, 10. | 71 05.0 | Oct. 31, Nov. 1, 2. | 4.346 | .2004 | 13.41 | .6182 | C. O. Boutelle. | M. 3, D. C. 8. |
| 13 | Wolftrap. | 37 24.0 | 76 14.7 | 1871 | May 11, 12, 13, 15. | 2 49.3 | May 13, 15. | 69 46.8 | May 17, 19, 20. | 4.610 | .2126 | 13.34 | .6150 | A. T. Mosman. | do. |
| 14 | Tangier. | 37 47.9 | 75 59.3 | 1871 | June 19, 20, 22. | 3 03.2 | June 17. | 70 11.6 | Juue 16, 20, 21. | 4.542 | .2094 | 13.40 | .6180 | do. | do. |
| 15 | Clark Mt. | 38 18.6 | 78 00.2 | 1871 | Aug. 21 to 26. | 1 46.8 | Aug. 31, Sept. 1. | 71 40.2? | Aug 29, 30. | 4.390 | .2024 | 13.96 | .6436 | C. O. Boutelle. | M. 6, D. C. 10. |
| 16 | Bull Run. | 38 52.8 | 77 42.3 | 1871 | Oct. 14, 16, 17. | 4 21.3? | Oct. 20, 21. | 71 18.9 | Oct. 18, 19, Nov. 3, 4, 6. | 4.334 | .1998 | 13.53 | .6237 | do. | do. |
| | Petersburg. | 37 14.4 | 77 23.9 | 1871 | Oct. | 1 29 | ............ | ..... | ............ | .... | .... | .... | .... | A. G. McIlwaine, jr. | Eng.'s transit. |
| 17 | North end Knott Island. | 36 33.9 | 75 55.3 | 1873 | Apr. 20, 21, 22. | 2 54.8 | Apr. 21, 22. | 68 52.5 | Apr. 23. | 4.760 | .2195 | 13.21 | .6090 | A. T. Mosman. | M. 6, D. C. 8. |
| | Cape Henry Light-house. | 36 55.6 | 76 00.4 | 1874 | Nov. 26, 27, 28. | 2 39.5 | Nov. 27, 28. | 69 19.0 | Nov. 26, 27, 28. | 4.629 | .2134 | 13.11 | .6042 | T. C. Hilgard. | Bache-Fund M., D. C. 19. |
| 18 | Williamsburg. | 37 16.3 | 76 42.7 | 1874 | Dec. 4, 5, 6, 8, 9. | 2 12.0 | Dec. 6, 7, 9, 10. | 69 27.6 | Dec. 4, 5, 6, 8, 9. | 4.631 | .2135 | 13.20 | .6085 | J. B. Baylor. | do. |
| 19 | Greenwood. | 38 02 | 78 47.1 | 1880 | June 7. | 2 18.8 | ........... | ...... | ........... | .... | ... | ... | ... | do. | Th. M. 9. |
| 20 | Covington. | 37 48 | 79 58 | 1881 | June 15, 16. | + 1 03.2 | June 15, 16. | 69 33.5 | June 15, 16. | 4.615 | .2128 | 13.21 | .6093 | do. | Th. M. 9, D. C. 18. |
| 21 | Wytheville. | 36 55 | 81 05 | 1881 | June 24, 25. | − 0 01.3 | June 24, 25. | 68 43.6 | June 24, 25. | 4.780 | .2204 | 13.17 | .6075 | do. | do. |
| 22 | Marion. | 36 48 | 81 31 | 1881 | June 30, July 2. | + 0 01.7 | June 30, July 2. | 68 25.7 | June 30, July 2. | 4.846 | .2234 | 13.18 | .6076 | do. | do. |

### WASHINGTON TERRITORY.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. Brit. units. | Horizontal force. C. G. S. units. | Total force. Brit. units. | Total force. C. G. S. units. | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Cape Disappointment, on beach | 46 16.7 | 124 02.8 | 1851 | July 5, 6, 7, 8, 9. | −20 19.1 | ... ........ | ...... | .. ........ | .... | .... | .... | .... | G. Davidson, F. A. Roe. | Th. M. III. |
| | Cape Disappointment, on top. | 46 16.6 | 124 03.0 | 1851 | July 14, 15, 16, 17, 18, 19. | −20 45.3 | .......... | ...... | .. ...... .. | .... | .... | . .. | .... | do. | do. |
| 2 | Scarborough Harbor. | 48 21.8 | 124 38.0 | 1852 | Aug. 17, 18, 19, 20, 21, 22, 23. | −21 29.9 | ........... | ...... | Sept. 7, 8. | 4.170 | .1923 | .... | .... | G. Davidson, J. Rockwell. | do. |
| | Nee-ah Bay. | 48 22 | 124 36.8 | 1855 | Aug. 13, 15, 16, 18. | −21 48.2 | Aug. 20, 22. | 71 07.0 | Aug. 13, 14, 15, 16 | 4.276 | .1972 | 13.21 | .6093 | W. P. Trowbridge. | M. 4. |
| 3 | Point Hudson, Port Townshend | 48 06.9 | 122 44.9 | 1856 | Aug. 17, 18, 19, 20. | −21 39.5 | ........... | ...... | ... ........ | .... | .... | .... | ... | G. Davidson. | Th. M. III. |
| 4 | Seattle. | 47 35.9 | 122 20.0 | 1871 | Sept. 27, 28, 29, 30, Oct. 2, 3. | −22 35.4? | Sept. 21. | 71 08.9 | Oct. 4, 5. | 4.252 | .1961 | 13.16 | .6069 | S. R. Throckmorton. | Th. M. 5. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cape Disappointment, on top. | 46 16.6 | 124 03.0 | 1873 | Oct. 19, 23. | −21 46.9 | ............ | ... .. | ............ | ... | .... | .... | .... | W. Eimbeck. | Th. M. III. |
| | Cape Disappointment, on beach | 46 16.7 | 124 02.8 | 1873 | Oct. 24, 27. | −21 26.5 | Oct. 22, 24, 25, 26, 27. | 69 13.7 | Oct. 29, 30. | 4.537 | 2092 | 12.79 | .5899 | do. | do. |
| | Nee-ah Bay. | 48 21.8 | 124 38.0 | 1881 | Oct. 11. | −22 44.2 | Oct. 10. | 71 04.4 | Oct. 11. | 4.144 | .1911 | 12.78 | .5892 | H. E. Nichols, Lieut. U. S. N., act. asst. C. and G. S. | Th. M. III, D. C. 10. |
| | Cape Disappointment, on beach | 46 16.7 | 124 02.8 | 1881 | Oct. 14. | −21 36 0 | Oct. 13, 15. | 69 17.7 | Oct. 14. | 4.482 | .2067 | 12.68 | .5846 | do. | do. |
| 5 | Ainsworth. | 46 14 | 119 03 | 1881 | Aug. 22, 23. | −21 24.5 | Aug. 23. | 70 37.8 | Aug. 22, 23. | 4.332 | .1997 | 13.06 | .6021 | J. S. Lawson. | Th. M. 8, D. C. 21. |
| 6 | Sixty-Mile Well. | 46 49 | 118 50 | 1881 | Aug. 25, 26. | −22 46.9? | Aug. 25. | 70 44.8 | Aug. 25. | 4.321 | .1992 | 13.10 | .6041 | do. | do. |
| 7 | Sprague. | 47 19 | 118 10 | 1881 | Aug. 27, 28. | −22 55.4 | Aug. 27, 28. | 71 05.8 | Aug. 27. | 4.299 | .1982 | 13.27 | .6118 | do. | do. |
| 8 | Spokane Falls. | 47 43 | 117 23 | 1881 | Aug. 30, 31, Sept. 1. | −21 39.4 | Aug. 30. | 72 13.3 | Aug. 30. | 4.170 | .1923 | 13.66 | .6298 | do. | do. |
| 9 | Pomeroy. | 46 31 | 117 40 | 1881 | Sept. 20, 21. | −21 33.5 | Sept. 20. | 70 20.2 | Sept. 20. | 4.406 | .2032 | 13.09 | .6039 | do. | do. |
| 10 | Walla Walla. | 46 03.9 | 118 20.5 | 1881 | Sept. 24, 25, 26. | −22 04.4 | Sept. 26. | 70 46.5 | Sept. 25. | 4.349 | .2005 | 13.21 | .6089 | do. | do. |
| 11 | Wallula. | 46 07 | 118 55 | 1881 | Sept. 29, 30, Oct. 1, 2. | −19 55.7 | Sept. 29, 30. | 70 24.9 | Sept. 29, 30, Oct. 1. | 4.391 | .2025 | 13.10 | .6041 | do. | do. |
| 12 | Lower Cascades. | 45 39 | 122 00 | 1881 | Oct. 22, 23. | −19 29.3 | ............ | ...... | Oct. 22, 23. | 4.496 | .2073 | .... | .... | do. | Th. M. 8. |
| 13 | Vancouver. | 45 37.5 | 122 39 | 1881 | Oct. 26, 27. | −20 53.3 | ............ | ...... | Oct. 26. | 4.547 | .2097 | .... | .... | do. | do. |
| 14 | Olympia. | 47 02.3 | 122 54.0 | 1881 | Nov. 2, 3, 4. | −21 34.6 | ............ | ...... | Nov. 4. | 4.283 | .1975 | .... | .... | do. | do. |
| | Seattle. | 47 35.9 | 122 20.0 | 1881 | Nov. 8, 9, 10, 11. | −22 02.5 | ............ | ...... | Nov. 10, 11. | 4.217 | .1944 | ... | .... | do. | do. |
| | Port Townshend. | 48 07.0 | 122 45.0 | 1881 | Nov. 16, 17, 18. | −21 26.9 | ............ | ...... | Nov. 17, 18. | 4.144 | .1911 | .... | .... | do. | do. |

## WEST VIRGINIA.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Clarksburg. | 39 16.9 | 80 20.4 | 1864 | Jan. 6. | − 0 30.3 | ............ | ...... | ............ | .... | .... | .... | .... | A. T. Mosman. | M. 1. |
| 2 | Grafton. | 39 20.6 | 80 01.7 | 1864 | Jan. 12. | + 1 51.4 | ............ | ...... | ..... ..... | .... | .... | .... | .... | do. | do. |
| 3 | Cameron. | 39 49.8 | 80 34.4 | 1864 | Jan. 14. | − 0 24.0 | ............ | ...... | ............ | ... | .... | .... | .... | do. | do. |
| 4 | Wheeling. | 40 04.1 | 80 43.6 | 1864 | Jan. 23. | − 2 00.5 | ............ | ...... | ............ | .... | .. .. | .... | ... | do. | do. |
| 5 | Parkersburg. | 39 16.9 | 81 34.2 | 1864 | Jan. 26. | − 1 17.6 | ............ | ...... | ... ........ | .... | .... | .... | .... | do. | do. |
| 6 | Pt. Pleasant. | 38 50.5 | 82 08.8 | 1864 | Jan. 29. | − 1 34.9 | ............ | ...... | . ......... | .... | .... | .... | .... | do. | do. |
| 7 | Charleston. | 38 21.3 | 81 38.0 | 1864 | Mar. 3. | − 0 37.3 | ............ | .. | ............ | .... | .... | .... | .... | do. | do. |
| | Clarksburg. | 39 16.9 | 80 20.4 | 1880 | Dec. 10, 11. | + 1 45.8 | Dec. 10, 11. | 70 44.8 | Dec. 10, 11. | 4.413 | .2035 | 13.38 | .6171 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | Wheeling. | 40 03.3 | 80 44 | 1881 | May 25, 26. | + 0 01.0 | May 25. | 71 54.5 | May 25, 26. | 4.208 | .1940 | 13.55 | .6247 | do. | do. |
| | Parkersburg. | 39 16.0 | 81 34 | 1881 | May 30, 31. | + 0 07.2 | May 31. | 70 58.6 | May 30, 31. | 4.402 | .2030 | 13.50 | .6228 | do. | do. |
| | Charleston. | 38 21.0 | 81 38.1 | 1881 | June 6, 7. | + 1 02.8 | June 6, 7. | 69 57.2 | June 6, 7. | 4.577 | .2110 | 13.35 | .6155 | do. | do. |
| 8 | Alderson. | 37 45 | 80 40 | 1881 | June 11, 13. | + 0 55.2 | June 11, 13. | 69 25.9 | June 11, 13. | 4.679 | .2157 | 13.32 | .6140 | do. | do. |

## WISCONSIN.

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Madison University. | 43 04.5 | 89 24.2 | 1876 | Oct. 10, 11, 12, 13, 14. | − 6 59.7? | Oct. 3, 4, 5, 6, 7, 9, 11, 12, 13, 14, 17. | 73 54.8 | Oct. 10, 11, 14, 15, 16. | 3.891 | .1794 | 14.04 | .6474 | F. E. Hilgard. | M. 6, D. C. 18. |
| | do. | 43 04.5 | 89 24.2 | 1877 | Aug. 30, Sept. 1, 3, 4, 5, 6, 7, 8, 10, 17, 21. | − 6 44.9? | Aug. 30, 31, Sept. 1, 5, 6, 10. | 73 55.5 | Aug. 29, 30, 31, Sept. 2, 3, 4, 5, 7, 10, 11, 13, 14. | 3.913 | .1804 | 14.13 | .6515 | A. Braid. | Th. M. 9, M. 6, D. C. 18. |
| | Madison, South Station. | 43 04.5 | 89 24.2 | 1877 | Sept. 21. | − 6 58.2? | ............ | ...... | ... ........ | .... | .... | .... | .... | C. A. Schott. | M. 6. |

## TABLES OF MAGNETIC RESULTS—Continued.

### WISCONSIN—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 2 | La Crosse. | 43 48.8 | 91 14.8 | 1877 | Sept. 24, 25, 26. | – 8 37.9 | Sept. 24, 25, 26. | 73 48.7 | Sept. 24, 25, 26. | 3.880 | .1789 | 13.92 | .6417 | A. Braid. | Th. M. 9, D. C. 18. |
| | Madison, University. | 43 04.5 | 89 24.2 | 1878 | Sept. 8, 9, 10, 11, 12, 13. | – 6 31.8 | Sept. 8, 9, 10, 11, 12, 13. | 73 56.5 | Sept. 8, 9, 10, 11, 12, 13. | 3.893 | .1795 | 14.07 | .6489 | W. Suess. | M. 6, D. C. 5. |
| | Madison, South Station. | 43 04.5 | 89 24.2 | 1878 | Sept. 14, 15. | – 6 32.0 | . . ........ | ...... | Sept. 14, 15. | 3.905 | .1801 | 14.12 | .6511 | do. | |
| 3 | Madison, Farm. | 43 04.5 | 89 25.2 | 1878 | Nov. 13, 14, 15. | – 6 31.7 | Nov. 18, 19. | 73 53.5 | Nov. 13, 14, 15. | 3.893 | .1795 | 14.03 | .6470 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | Madison, University. | 43 04.5 | 89 24.2 | 1878 | Nov. 22, 23, 25. | – 6 22.9 | Nov. 21, 23, 26 | 73 55.1 | Nov. 22, 23. | 3.894 | .1795 | 14.06 | .6480 | do. | do. |
| | Madison, South Station. | 43 04.5 | 89 24.2 | 1878 | Nov. 26. | – 6 33.5 | ...... ..... | ...... | .......... | .... | .... | .... | .... | do. | Th. M. 9. |
| | Madison, University. | 43 04.5 | 89 24.2 | 1879 | Sept. 22, 24, 25, 26, 27, 29, 30, Oct. 1, 10, 11. | – 6 26.8 | Sept. 23, 24, 26, 27, 30, Oct. 1, 10, 11. | 73 51.0 | Sept. 27, Oct. 1, 10, 11. | 3.903 | .1800 | 14.03 | .6471 | D. Mason. | M. 6, D. C. 5. |
| | Madison, South Station. | 43 04.5 | 89 24.2 | 1879 | Oct. 2, 3, 4. | – 6 17.2 | Oct. 3. | 73 49.7 | Oct. 2, 3. | 3.914 | .1805 | 14.05 | .6481 | do. | do. |
| | Madison, Farm. | 43 04.5 | 89 25.2 | 1879 | Oct. 6, 7, 8, 9. | – 6 30.9 | Oct. 7, 8, 9. | 73 50.7 | Oct. 7, 8, 9. | 3.908 | .1802 | 14.05 | .6476 | do. | do. |
| | Madison, University. | 43 04.5 | 89 24.2 | 1880 | Sept. 15, 16, 17, 18, 21, 22. | – 6 20.9 | Sept. 16, 17, 18, 20, 21. | 73 49.5 | Sept. 15, 16, 17, 18, 20, 21, 22. | 3.900 | .1798 | 14.00 | .6454 | do. | do. |
| | Madison, Farm. | 43 04.5 | 89 25.2 | 1880 | Sept. 23, 24, 25, 27, 28. | – 6 22.9 | Sept. 23, 24, 25. | 73 44.5 | Sept. 23, 24, 25. | 3.905 | .1801 | 13.95 | .6433 | do. | do. |
| 4 | Superior City. | 46 40 | 92 04 | 1880 | Aug. 21, 23. | – 9 45.4 | Aug. 21. | 76 26.1 | Aug. 21, 23. | 3.261 | .1504 | 13.90 | .6412 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | Madison, Farm. | 43 04.5 | 89 25.2 | 1881 | Dec. 16, 17, 18, 19. | – 6 21.0 | Dec. 16, 17, 18, 19 | 73 48.1 | Dec. 16, 17, 18, 19 | 3.898 | .1797 | 13.97 | .6442 | W. Suess. | M. 6, D. C. 5. |

### WYOMING.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| 1 | Sherman. | 41 07.8 | 105 23.6 | 1872 | July 31, Aug. 1, 2. | –15 52.6 | Aug. 6. | 68 53.3 | Aug. 3, 5. | 4.768 | .2198 | 13.24 | .6104 | W. Suess (R. D. Cutts) | M. 3, D. C. 8. |
| 2 | Cheyenne. | 41 08 | 104 49.0 | 1878 | Sept. 13, 14. | –15 20.5 | Sept. 13, 14, 17. | 68 54.4 | Sept. 13, 16, 17. | 4.738 | .2185 | 13.16 | .6071 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| 3 | Laramie City. | 41 18.9 | 105 35.6 | 1878 | Sept. 20, 21. | –15 07.4 | ............ | ..... | ... ... .... | .... | .... | .... | .... | do. | Comp. of Th. M. 9. |
| 4 | Rock Creek. | 41 50 | 106 05 | 1878 | Sept. 23. | –15 45.8 | ............ | ...... | ............ | .... | ... | .... | .... | do. | do. |
| 5 | Fort Fred. Steele. | 41 46.7 | 106 56.8 | 1878 | Sept 26, 27. | –16 10.1 | Sept. 28, 29. | 69 00.2 | Sept. 26, 27. | 4.707 | .2170 | 13.14 | .6056 | do. | Th. M. 9, D. C. 18. |
| 6 | Creston. | 41 48 | 107 57 | 1878 | Oct. 1, 2. | –16 03.8 | ............ | ...... | ............ | .... | .... | .... | .... | do. | Comp. of Th. M. 9. |
| 7 | Point of Rocks. | 41 43 | 108 58 | 1878 | Oct. 3. | –16 17.8 | ............ | ...... | ...... ..... | .... | .... | ... | .... | do. | do. |
| 8 | Green River. | 41 32 | 109 29 | 1878 | Oct. 7, 8, 9. | –16 46.2 | Oct. 5, 10. | 68 17.1 | Oct. 7, 8, 9. | 4.813 | .2219 | 13.01 | .5998 | do. | Th. M. 9, D. C. 18. |
| 9 | Carter. | 41 36 | 110 26 | 1878 | Oct. 11, 12. | –17 06.3 | ............ | ...... | ............ | .... | .... | .... | .... | do. | Comp. of Th. M. 9. |

### FOREIGN COUNTRIES.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| 1 | Quebec, Canada. | 46 48.4 | 71 14.5 | 1859 | July 19. | +16 17 | July 18. | +77 17.5 | July 19. | 2.991 | .1379 | 13.60 | .6268 | C. A. Schott. | M. 6, D. C. 9. |
| 2 | Montreal, Canada. | 45 30.5 | 73 34.9 | 1859 | July 20. | +12 21 | July 20. | 76 51.4 | July 20. | 3.111 | .1434 | 13.68 | .6307 | do. | do. |
| 3 | Chamcook, Canada. | 45 07.5 | 67 04.9 | 1859 | Oct. 13, 14, 15. | +17 35.7 | Oct. 13. | 76 09.4 | Oct. 17, 20. | 3.241 | .1494 | 13.54 | .6244 | G. W. Dean (A. D. Bache). | M. 1, D. C. 4. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 4 | Aulezavik Island, Labrador. | 59 47.5 | 64 13.2 | 1860 | July 16, 17, 18, 19. | +51 23.5 | July 16, 17, 18, 19, 20. | 82 13.3 | July 16, 17, 18, 19, 20. | 1.696 | .0782 | 12.53 | .5778 | E. Goodfellow, S. Walker. | do. |
| 5 | *St. Pierre de Miquelon, Gulf of St. Lawrence.* | 46 46.9 | 56 10.6 | 1872 | June, July, Aug. | +29 25.5 | June 20, 21, 24, 25. | 74 37.9? | June 28, 29. | 3.193 | .1472 | 12.05? | .5554? | E. Goodfellow. | M. 6, D. C. 4. |
| 6 | San Martin Island, Lower California. | 30 28.9 | 116 06.8 | 1873 | Feb. 1. | −13 20.5 | ..... ..... | ...... | ....... .. | .... | .... | .... | ... | W. Eimbeck (G. Davidson). | Th. M. III. |
| 7 | Lagoon Head, Lower California | 28 14.4 | 114 06.4 | 1873 | Feb. 13. | −11 50.8 | ........... | ... .. | ........ ... | .... | .... | .... | .... | do. | do. |
| 8 | Cerros Island, Lower California | 28 03.9 | 115 11.5 | 1873 | Feb. 17, 18. | −11 45.2 | Feb. 17. | 52 30.5? | Feb. 17. | 6.505 | .2999 | 10.69 | .4928 | do. | Th. M. III, Barrow & Owen, D. C. |
| 9 | San José del Cabo, Lower California. | 23 03.6 | 109 40.7 | 1873 | Feb. 27, 28, Mar. 1 | −10 32.4 | Feb. 27, 28. | 47 25.2 | Feb. 27, 28. | 7.007 | .3231 | 10.36 | .4775 | do. | do. |
| 10 | Magdalena Bay, Lower California. | 24 38.4 | 112 08.9 | 1873 | Mar. 7. | −10 36.6 | Mar. 6, 7. | 48 09.0 | Mar. 7 | 6.926 | .3193 | 10.38 | .4786 | do. | do. |
| 11 | Ascension Island, Lower California. | 27 06.4 | 114 18.2 | 1873 | Mar. 14. | −11 26.4 | ........... | ...... | .......... | .... | .... | .... | .... | do. | |
| 12 | Chatham Island, South Pacific. | −43 49.0 | 176 39.8 | 1874 | Dec. 1, 2, 3. | −15 09.7 | Nov. 23. | −65 59.1 | Dec. 6, 7, 29, 30. | 5.211 | .2403 | 12.80 | .5904 | E. Smith, A. H. Scott. | Tr. of Venus M. 5, D. C. 105. |
| 13 | Nassau, New Providence, on Hog Island. | 25 05.5 | 77 20.0 | 1879 | Feb. 19, 21, 22. | − 1 25.6 | Feb. 18, 19, 20. | 55 50.5 | Feb. 18, 19, 20. | 6.503 | .2998 | 11.58 | .5339 | Lieut. S. M. Ackley, U. S. N., act. asst. C. & G. S. | Th. M. 8, D. C. 19. |
| 14 | South Bemini, Bahama Islands. | 25 42 | 79 17.6 | 1879 | Feb. 24, 25, 26. | − 2 27.9 | Feb. 24, 25, 26. | 56 20.3 | Feb. 24, 25, 26. | 6.448 | .2973 | 11.63 | .5364 | do. | do. |
| 15 | Water Cay, Salt Key Banks. | 23 59.2 | 80 20.8 | 1879 | Feb. 28. | − 2 50.7 | Feb. 28. | 53 41.6 | Feb. 28. | 6.742 | .3109 | 11.39 | .5251 | do. | do. |
| 16 | Matanzas, Cuba. | 23 02.9 | 81 36.9 | 1879 | Mar. 6, 7, 8. | − 3 26.4 | Mar. 6, 7, 8. | 52 23.4 | Mar. 6, 7, 8. | 6.823 | .3146 | 11.18 | .5155 | do. | do. |
| 17 | Havana, Cuba. | 23 08.2 | 82 21.3 | 1879 | Mar. 13, 14, 15. | − 3 53.8 | Mar. 13, 15, 16. | 52 18.1 | Mar. 13, 15, 16. | 6.847 | .3157 | 11.20 | .5163 | do. | do. |
| 18 | Bahia Honda, Cuba. | 22 58.4 | 83 12 | 1879 | Mar. 28, 29, 31. | − 4 03.4 | Mar. 28, 29, 31. | 52 18.4 | Mar. 28, 29, 31. | 6.858 | .3162 | 11.22 | .5171 | do. | do. |
| 19 | Cape San Antonio, Cuba. | 21 55.5 | 84 55 | 1879 | Apr. 7, 8, 9. | − 4 44.0 | Apr. 7, 8, 9. | 50 14.9 | Apr. 7, 8, 9. | 7.035 | .3244 | 11.00 | .5073 | do. | do. |
| 20 | Belize, British Honduras. | 17 29 | 88 12.3 | 1879 | Apr. 15, 16, 17. | − 5 47.2 | Apr. 15, 16, 18. | 43 32.3 | Apr. 15, 16, 18. | 7.425 | .3424 | 10.24 | .4723 | do. | do. |
| 21 | Cozumel. | 20 33 | 86 57 | 1879 | Apr. 24, 25, 26. | − 5 12.3 | Apr. 23, 24, 25. | 48 06.5 | Apr. 23, 24, 25. | 7.176 | .3309 | 10.75 | .4956 | do. | do. |
| 22 | Mugeres Island. | 21 14.7 | 86 45.7 | 1879 | Apr. 28, 29, 30. | − 4 49.3 | Apr. 28, 29 30. | 49 32.9 | Apr. 28, 29, 30. | 7.063 | .3257 | 10.89 | .5020 | do. | do. |
| 23 | Halifax, Nova Scotia, | 44 39.5 | 63 35.0 | 1879 | Sept. 8, 10. | +20 43.3 | Sept. 8, 10. | 74 39.2 | Sept. 8, 10. | 3.452 | .1592 | 13.04 | .6015 | J. B. Baylor. | Th. M. 9, D. C. 18. |
| | Quebec, Canada. | 46 48.4 | 71 14.5 | 1879 | Sept. 16, 19. | +17 13.7 | Sept. 16, 19. | 76 45.1 | Sept. 16, 19. | 3.104 | .1431 | 13.54 | .6244 | do. | do. |
| | Montreal, Canada. | 45 30.5 | 73 34.9 | 1879 | Sept. 25. | +13 40.5 | Sept. 25. | 76 25.7 | Sept. 25. | 3.191 | .1471 | 13.60 | .6269 | do. | do. |
| 24 | Perez Island. | 22 23.5 | 89 42.0 | 1880 | Jan. 21, 22, 23. | − 6 19.2 | Jan. 22, 23. | 50 09.7 | Jan. 22, 23. | 7.055 | .3253 | 11.01 | .5078 | S. M. Ackley. | Th. M. 8, D. C. 19. |
| 25 | Arenas Cay. | 22 07.2 | 91 24.9 | 1880 | Jan. 28, 29. | − 6 32.9 | Jan. 28, 29. | 49 35.8 | Jan. 29. | 7.103 | .3275 | 10.96 | .5053 | do. | do. |
| 26 | Vera Cruz, Mexico. | 19 12.2 | 96 08.5 | 1880 | Feb. 10, 11, 12. | − 7 26.3 | Feb. 10, 11, 12. | 44 04.6 | Feb. 10, 11, 12. | 7.391 | .3408 | 10.29 | .4744 | do. | do. |
| 27 | Coatzacoalcos, Mexico. | 18 08 | 94 26 | 1880 | Feb. 20, 21, 23. | − 7 10.5 | Feb. 20, 21, 23. | 43 03.3 | Feb. 20, 21, 23. | 7.398 | .3411 | 10.12 | .4668 | do. | do. |
| 28 | Laguna de Terminos, Gulf of Campeche. | 18 38 | 93 00 | 1880 | Mar. 2, 3, 4. | − 6 39.9 | Mar. 2, 3, 4. | 44 18.3 | Mar. 2, 4. | 7.353 | .3390 | 10.28 | .4737 | do. | do. |
| 29 | Campeche, Yucatan. | 19 50.5 | 90 33.3 | 1880 | Mar. 8, 9, 10. | − 6 36.7 | Mar. 8, 9, 10. | 46 20.7 | Mar. 8, 9, 10. | 7.229 | .3333 | 10.48 | .4828 | do. | do. |
| 30 | Progresso, Yucatan. | 21 16.8 | 89 39.5 | 1880 | Mar. 12, 13, 15. | − 6 25.7 | Mar. 13, 15. | 48 52.3 | Mar. 13. | 7.090 | .3269 | 10.78 | .4970 | do. | do. |
| 31 | Victoria, Vancouver Island. | 48 25.8 | 123 22.2 | 1880 | .............. | ...... | May 4. | 71 22.1 | May 4. | 4.106 | .1893 | 12.85 | .5925 | W. H. Dall, M. Baker. | D. C. 21. |
| 32 | Departure Bay, Vancouver Island. | 49 12.6 | 123 58.5 | 1880 | ... .......... | ...... | May 6. | 71 29.2 | ............ | .... | .... | .... | .... | do. | do. |
| 33 | Plover Bay, Eastern Siberia. | 64 22.0 | 173 21.5 | 1880 | Aug. 12, Sept. 13. | −18 25.5 | Aug. 12, Sept. 13 | 74 46.4 | Aug. 12, Sept. 13 | 3.262 | .1504 | 12.42 | .5727 | do. | Mag'c. Th. 123, D. C. 21. |
| 34 | Big Diomede Isl'd, Bering Strait | 65 44.9 | 169 04.4 | 1880 | Sept. 10. | −21 49.2 | Sept. 10. | 76 15.0 | Sept. 10. | 2.981 | .1374 | 12.54 | .5781 | do. | do. |
| 35 | Michipicoten, Canada. | 47 56.0 | 84 50.6 | 1880 | July 21, Sept. 9. | + 1 20.5 | ............ | ...... | July 21, Sept. 9. | 2.860 | .1319 | .... | .... | Lt. S. W. Very, U. S. N., act. asst. C. & G. S. | Bache-Fund M. |
| 36 | Foot of Long Portage, Canada | 47 54.6 | 84 45.0 | 1880 | July 24, Sept. 8. | + 3 14.0 | ............ | ...... | July 24, Sept. 8. | 2.818 | .1299 | .... | .... | do. | do. |
| 37 | Big Stony Portage, Canada. | 48 13 6 | 84 15.3 | 1880 | July 27. | + 4 12.1 | ........ .. | ... .. | July 27, Sept. 7. | 2.750 | .1268 | .... | .... | do. | do. |
| 38 | Sandy Beach, Dog Lake, Can. | 48 17.8 | 84 00.7 | 1880 | July 28. | + 1 19.3 | ... ........ | ...... | July 28. | 2.784 | .1284 | .... | .. . | do. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### FOREIGN COUNTRIES—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. | | Total force. | | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. | | |
| | | ° ′ | ° ′ | | | ° ′ | | ° ′ | | | | | | | |
| 39 | Fairy Point, Missinaibi Lake, Canada. | 48 20.7 | 83 44.0 | 1880 | July 29. | + 3 22.2 | .......... | ..... | July 29. | 2.751 | .1268 | .... | .... | S. W. Very. | Bache-Fund M. |
| 40 | Missinaibi, Canada. | 48 28.6 | 83 28.4 | 1880 | July 30, Aug. 1, 2. | + 2 21.2 | .......... | ...... | Aug. 2. | 2.720 | .1254 | .. | .... | do. | do. |
| 41 | Twin Portage, Canada. | 49 12.3 | 83 24.4 | 1880 | Aug. 5, 6. | + 4 58.1 | .......... | ...... | Aug. 6. | 2.638 | .1216 | .... | ... | do. | do. |
| 42 | Kettle Portage, Canada. | 49 47.1 | 83 16.4 | 1880 | Aug. 8. | + 4 15.1 | .......... | ...... | Aug. 8. | 2.474 | .1141 | .... | .... | do. | do. |
| 43 | Near Cedar Island, Moose River, Canada. | 50 21.1 | 82 42.2 | 1880 | Aug. 11, 28. | + 5 14.5 | .......... | ...... | Aug 28. | 2.453 | .1131 | .... | .... | do. | do. |
| 44 | Near Small Falling Brook, Moose River, Canada. | 50 36.4 | 82 07.2 | 1880 | Aug, 12. | + 7 56.9 | .......... | ...... | Aug. 11, 12. | 2.312 | .1066 | ... | .... | do. | do. |
| 45 | Moose Factory, Canada. | 51 15.4 | 80 40.5 | 1880 | Aug. 14, 17, 20. | +15 27.5 | .......... | ..... | Aug. 15, 20. | 2.110 | .0973 | .... | .... | do. | do. |
| 46 | Camp near Gypsum Beds, Can. | 50 50.0 | 81 15.4 | 1880 | Aug. 25. | + 9 52.9 | .......... | ...... | .......... | ... | .... | .... | .... | do. | do. |
| 47 | Long Gravel Bed, Moose River, Canada. | 50 43.6 | 81 47.8 | 1880 | Aug. 26. | + 8 01.9 | .......... | ...... | .......... | ... | .... | .... | .... | do. | do. |
| 48 | Store House Portage, Canada. | 50 04.1 | 83 16.1 | 1880 | Aug. 29, 30. | + 4 54.6 | .......... | ...... | Aug. 29. | 2.470 | .1039 | .... | ... | do. | do. |
| 49 | Albany Rapids, Moose River, Canada. | 49 22.0 | 83 29.8 | 1880 | Sept. 2. | + 4 11.0 | .......... | ...... | Sept. 2. | 2.540 | .1171 | .... | .... | do. | do. |
| 50 | Moose River, just above a small cascade, Canada. | 49 07.7 | 83 21.9 | 1880 | Sept. 3. | + 4 20.4 | .......... | ...... | Sept. 3. | 2.589 | .1194 | .... | .... | do. | do. |
| 51 | St. Paul's Portage, Canada. | 48 49.5 | 83 23.5 | 1880 | Sept. 3, 4. | + 4 10.2 | .......... | ...... | Sept. 3. | 2.643 | .1219 | .... | .... | do. | do. |
| 52 | Foot of swampy grounds Portage, Canada. | 48 41.5 | 83 23.6 | 1880 | Sept. 5. | + 0 12.7 | .......... | ...... | Sept. 5. | 2.752 | .1269 | ... | .... | do. | do. |
| 53 | Clarion Island, off Lower California. | 18 19.6 | 114 41.9 | 1880 | Oct. 9. | − 8 23 | Oct. 8. | 39 34.0 | Oct. 9. | 7.357 | .3392 | 9.54 | .4400 | Lt. H. E. Nichols, U. S. N., act. asst. C. & G. S. | Th. M. III, D. C. 10. |
| 54 | Socorro Island, off Lower California. | 18 42.8 | 110 54.2 | 1880 | Oct. 12. | − 8 49.6 | Oct. 11. | 41 18.7 | Oct. 12. | 7.513 | .3464 | 10.00 | .4612 | do. | do. |
| 55 | La Union, Chiquiriu Point, San Salvador. | 13 17.2 | 87 46.4 | 1880 | Nov. 3. | − 5 59.0 | Nov. 1, 3. | 38 23.9 | Nov. 2. | 7.284 | .3359 | 9.29 | .4286 | do. | do. |
| 56 | Acajutla, San Salvador. | 13 34.1 | 89 50.7 | 1880 | Nov. 7. | − 6 15.3 | Nov. 6. | 37 49.7 | Nov. 7. | 7.498 | .3457 | 9.49 | .4377 | do. | do. |
| 57 | Champerico, Guatemala. | 14 17.6 | 91 55.0 | 1880 | Nov. 10. | − 7 00.4 | .......... | ...... | .......... | .... | .... | .... | .... | do. | Th. M. III. |
| 58 | Salina Cruz, Tehuantepec, Mexico. | 16 09.6 | 95 26.7 | 1880 | Nov. 14, 15. | − 7 17.2 | Nov. 13, 14. | 40 08.5 | Nov. 14, 15. | 7.479 | .3448 | 9.78 | .4510 | do. | Th. M. III, D. C. 10. |
| 59 | Port Escondido, Mexico. | 16 04.1 | 96 56.7 | 1880 | Nov. 19. | − 7 41.7 | Nov. 17. | 39 13.2 | Nov. 17, 18. | 7.504 | .3460 | 9.68 | .4466 | do. | do. |
| 60 | Acapulco, Mexico. | 16 49.2 | 99 56.3 | 1880 | Nov. 23, 24. | − 7 56.6 | Nov. 22, 24. | 40 08.5 | Nov. 23, 24. | 7.518 | .3466 | 9.83 | .4534 | do. | do. |
| 61 | Isla Grande, Mexico. | 17 40.5 | 101 41.4 | 1880 | Nov. 28. | − 7 26.4 | .......... | ...... | .......... | .... | .... | .... | .... | do. | Th. M. III. |
| 62 | Manzanilla, Mexico. | 19 02.8 | 104 20.5 | 1880 | Dec. 1. | − 8 05.0 | Nov. 30. | 43 15.8 | Dec. 1. | 7.320 | .3375 | 10.05 | .4635 | do. | Th. M. III, D. C. 10. |
| 63 | San Blas, Mexico. | 21 32.2 | 105 18.1 | 1880 | Dec. 5. | − 9 18.1 | Dec. 4. | 46 20.8 | Dec. 5. | 7.204 | .3322 | 10.43 | .4812 | do. | do. |
| 64 | Point San Ignacio, Mexico. | 25 36.5 | 109 17.3 | 1880 | . 20. | −10 15.3 | .......... | ...... | .......... | .... | ... | .... | .... | do. | Th. M. III. |
| 65 | Santa Barbara Bay, Mexico. | 26 41.5 | 109 38.4 | 1880 | Dec. 23. | −10 48.4 | Dec. 22. | 52 21.2 | Dec. 23. | 6.735 | .3105 | 11.03 | .5084 | do. | Th. M. III, D. C. 10. |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 66 | Guaymas, Mexico. | 27 54.8 | 110 52.6 | 1880 | Dec. 28. | —11 48.0 | Dec. 27. | 52 58.0 | Dec. 28. | 6.619 | .3052 | 10.99 | .5067 | H. E. Nichols. | do. |
| 67 | Tiburon Island, Mexico. | 29 11.5 | 112 27.0 | 1880<br>1881 | Jan. 1. | —11 59.3 | Dec. 31. | 54 59.2 | Jan. 1. | 6.477 | .2986 | 11.29 | .5204 | do. | do. |
| 68 | Rocky Point, Mexico. | 31 17.2 | 113 33.1 | 1881 | Jan. 5. | —13 27.0 | Jan. 4. | 57 14.7 | | [illegible] | .2882 | 11.55 | .5327 | do. | do. |
| 69 | Philipps' Point, Mexico. | 31 46.1 | 114 43.4 | 1881 | Jan. 9, 10. | —13 05.7 | Jan. 8. | 57 31.8 | Jan. 9, 10. | 6.184 | .2851 | 11.52 | .5311 | do. | do. |
| 70 | Point San Felipe, Lower California. | 31 02.1 | 114 49.8 | 1881 | Jan. 13. | —12 57.2 | Jan. 12. | 56 25.2 | Jan. 13. | 6.272 | .2892 | 11.34 | .5229 | do. | do. |
| 71 | San Luis Gonzales, Lower California. | 29 50.9 | 114 25.4 | 1881 | Jan. 15. | —12 27.3 | Jan. 14. | 55 11.3 | Jan. 15. | 6.425 | .2962 | 11.25 | .5189 | do. | do. |
| 72 | Santa Teresa Bay, Lower California. | 28 25.1 | 112 51.9 | 1881 | Jan. 18. | —11 42.0 | Jan. 17. | 53 49.0 | Jan. 18. | 6.571 | .3030 | 11.13 | .5132 | do. | do. |
| 73 | Santa Maria Cove, Lower California. | 27 25.2 | 112 19.5 | 1881 | Jan. 20. | —11 06.3 | Jan. 19. | 52 56.8 | Jan. 20. | 6.681 | .3080 | 11.09 | .5112 | do. | do. |
| 74 | Mulege, Lower California. | 26 53.8 | 111 58.2 | 1881 | Jan. 25. | —11 13.4 | Jan. 24. | 52 05.5 | Jan. 25. | 6.724 | .3100 | 10.94 | .5046 | do. | do. |
| 75 | Loreto, Lower California. | 26 01.1 | 111 20.5 | 1881 | Jan. 28. | —10 16.3 | Jan. 27. | 51 00.8 | Jan. 28. | 6.789 | .3130 | 10.79 | .4975 | do. | do. |
| 76 | Isle San Josef, Lower California. | 24 55.0 | 110 37.3 | 1881 | Feb. 1. | — 9 47.6 | Jan. 31. | 49 38.5 | Feb. 1. | 6.838 | .3153 | 10.56 | .4869 | do. | do. |
| 77 | Pichilingue Bay, Lower California. | 24 15.5 | 110 20.1 | 1881 | Feb. 5. | — 9 45.1 | Feb. 5. | 49 48.5 | Feb. 5. | 6.885 | .3175 | 10.67 | .4920 | do. | do. |
| 78 | La Paz, El Mogote, Lower California. | 24 10.2 | 110 20.7 | 1881 | Feb. 7. | —10 09.2 | Feb. 6. | 49 10.1 | Feb. 7. | 7.023 | .3238 | 10.74 | .4952 | do. | do. |
| 79 | Mazatlan, Mexico. | 23 11.5 | 106 26.6 | 1881 | Feb. 13. | — 9 39.4 | Feb. 12. | 48 15.8 | Feb. 13. | 7.049 | .3250 | 10.59 | .4882 | do. | do. |
| | San José del Cabo, Lower California. | 23 03.6 | 109 41.2 | 1881 | Feb. 18. | — 9 43.8 | ............ | ...... | ........... | .... | .... | .... | .... | do. | Th. M. III. |
| 80 | Cape San Lucas, Lower California. | 22 53.6 | 109 54.7 | 1881 | Feb. 20. | — 9 26.2 | Feb. 19, 20. | 47 23.2 | Feb. 20. | 7.193 | .3275 | 10.49 | .4837 | do. | Th.M.III,D.C.10. |
| | Magdalena Bay, Lower California. | 24 38.4 | 112 08.9 | 1881 | Feb. 24. | —10 29.1 | Feb. 24. | 48 18.7 | Feb. 24. | 7.032 | .3242 | 10.57 | .4875 | do. | do. |
| 81 | Pequeña Bay, Lower California. | 26 15.9 | 112 28.5 | 1881 | Feb. 28. | —10 31.1 | Feb. 28. | 51 48.1 | Feb. 28. | 6.689 | .3084 | 10.82 | .4987 | do. | do. |
| 82 | Point Abreojos, Lower California. | 26 47.0 | 113 31.2 | 1881 | Mar. 3. | —11 15.5 | Mar. 2. | 51 47.7 | Mar. 3. | 6.705 | .3092 | 10.84 | .4999 | do. | do. |
| | Ascension Island. | 27 06.0 | 114 18.4 | 1881 | Mar. 5. | —11 23.0 | Mar. 4. | 51 43.4 | Mar. 5. | 6.710 | .3094 | 10.83 | .4994 | do. | do. |
| | Cerros Island. | 28 03.4 | 115 11.3 | 1881 | Mar. 9. | —11 58.6 | Mar. 7. | 52 55.0 | Mar. 8. | 6.603 | .3045 | 10.95 | .5050 | do. | do. |
| 83 | Guadalupe Island, Lower California. | 28 55.3 | 118 15.1 | 1881 | Mar. 19. | —12 54.8 | Mar. 18. | 53 38.9 | Mar. 18. | 6.421 | .2961 | 10.83 | .4995 | do. | do. |
| 84 | San Geronimo Island, Lower California. | 29 47.2 | 115 47.7 | 1881 | Mar. 25, 26. | —12 42.2 | Mar. 23. | 54 30.0 | Mar. 25. | 6.430 | .2965 | 11.07 | .5106 | do. | do. |
| | San Martin Island, Lower California. | 30 29.4 | 116 07.2 | 1881 | Mar. 30. | —12 55.7 | Mar. 29. | 55 34.4 | Mar. 30. | 6.377 | .2940 | 11.28 | .5200 | do. | do. |
| 85 | Todos Santos, Lower California. | 31 51.4 | 116 37.6 | 1881 | Apr. 3. | —12 00.8 | Apr. 2, 3. | 58 30.6 | Apr. 3. | 6.044 | .2787 | 11.57 | .5336 | do. | do. |
| 86 | Waddington Harbor, British Columbia. | 50 54.0 | 124 49.5 | 1881 | July 30. | —25 22.0 | July 30. | 71 58.6 | July 30. | 4.005 | .1847 | 12.94 | .5969 | do. | do. |
| 87 | Anchorage Cove, Kingcome Inlet, British Columbia. | 50 52.8 | 126 11.7 | 1881 | Aug. 3. | —25 42.7 | Aug. 3. | 72 46.1 | Aug. 3. | 3.808 | .1756 | 12.86 | .5928 | do. | do. |
| 88 | Port McLaughlin, British Columbia. | 52 08.4 | 128 10.3 | 1881 | Aug. 7. | —26 42.9 | Aug. 5, 6. | 73 12.1 | Aug. 7. | 3.785 | .1745 | 13.10 | .6038 | do. | do. |

## TABLES OF MAGNETIC RESULTS—Continued.

### FOREIGN COUNTRIES—Continued.

| No. | Name of stations. | Lat. | Long. | Year. | Month and day. | Decl'n. | Month and day. | Dip. | Month and day. | Horizontal force. |  | Total force. |  | Observer. | Instruments. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  |  | Brit. units. | C. G. S. units. | Brit. units. | C. G. S. units. |  |  |
|  |  | ° ′ | ° ′ |  |  | ° ′ |  | ° ′ |  |  |  |  |  |  |  |
| 89 | Port Simpson, British Columbia. | 54 33.6 | 130 22.8 | 1881 | Aug. 10, 12. | −27 54.1 | Aug. 9. | 74 21.0 | Aug. 10, 12. | 3.503 | .1615 | 12.98 | .5987 | H. E. Nichols. | Th. M. III, D. C. 10. |
| 90 | Rose Harbor, Queen Charlotte Island, British Columbia. | 52 09.1 | 131 15.0 | 1881 | Sept. 20. | −26 00.6 | Sept. 19. | 72 30.2 | Sept. 20. | 3.885 | .1791 | 12.92 | .5957 | do. | do. |
| 91 | North Harbor, Quatsino Sound, British Columbia. | 50 29.4 | 128 03.6 | 1881 | Sept. 24, 25. | −24 53.7 | Sept. 22. | 71 41.3 | Sept. 24, 25. | 4.050 | .1867 | 12.89 | .5942 | do. | do. |
| 92 | Friendly Cove, Vancouver Island. | 49 35.5 | 126 37.5 | 1881 | Sept. 27. | −23 36.2 | Sept. 26. | 71 33.0 | Sept. 27. | 4.083 | .1883 | 12.90 | .5950 | do. | do. |
| 93 | Esquimalt, Vancouver Island. | 48 25.4 | 123 26.3 | 1881 | Sept. 30, Oct. 2. | −22 55.6 | Sept. 29. | 71 30.3 | Sept. 30, Oct. 1. | 4.080 | .1881 | 12.87 | .5930 | do. | do. |
|  | Departure Bay, British Columbia. | 49 12.6 | 123 57 | 1881 | Oct. 7. | −23 55.6 | Oct. 6. | 71 42.2 | Oct. 7. | 4.066 | .1875 | 12.95 | .5973 | do. | do. |
| 94 | Twillingate, Newfoundland. | 49 39.2 | 54 46.2 | 1881 | July 11, 12, 13, 16. | +33 59.2 | July 9, 11, 16. | 75 57 | July 11, 12, 13. | 3.050 | .1406 | 12.56 | .5792 | Lieut. S. W. Very, U. S. N., act. asst. C. & G. S. | Bache-Fund M. D. C. 20. |
| 95 | Turnavik, Labrador. | 55 14.9 | 59 19.0 | 1881 | July 28, 29. | +40 22.8 | July 28, 29. | 79 56 | July 28, 29. | 2.243 | .1034 | 12.83 | .5916 | do. | do. |
| 96 | Grady, Labrador. | 53 48.2 | 56 25.3 | 1881 | Aug. 3, 4. | +39 03.8 | Aug. 3, 4, 5. | 77 49 | Aug. 3, 4. | 2.775 | .1279 | 13.15 | .6060 | do. | do. |
| 97 | Nain, Labrador. | 56 32.7 | 61 40.7 | 1881 | Aug. 11, 15, 17, 18. | +44 50.2 | Aug. 11, 14, 19. | 78 22 | Aug. 11, 15, 19. | 2.607 | .1202 | 12.93 | .5961 | do. | do. |
| 98 | Battle Harbor, Labrador. | 52 16.3 | 55 34.5 | 1881 | Sept. 5, 6, 7, 8. | +37 12.7 | Sept. 6, 7, 8, 9. | 77 16 | Sept. 6, 7, 8. | 2.770 | .1277 | 12.57 | .5794 | do. | do. |
| 99 | St. John's, Newfoundland. | 47 34.4 | 52 41.9 | 1881 | Sept. 26, 27, 28. | +30 37.3 | Sept. 26, 27, 28. | 74 37 | Sept. 26, 27, 28. | 3.300 | .1522 | 12.44 | .5737 | do. | do. |
|  | St. Pierre de Miquelon, Gulf of St. Lawrence. | 46 46.8 | 56 10.6 | 1881 | Oct. 11, 12, 13. | +28 20.8 | Oct. 11, 13, 14. | 75 02 | Oct. 11, 12, 13. | 3.255 | .1501 | 12.60 | .5812 | do. | do. |
| 100 | Sydney, Cape Breton, Nova Scotia. | 46 08.6 | 60 11.6 | 1881 | Oct. 21, 22. | +25 11.8 | Oct. 21, 22. | 75 10 | Oct. 21, 22. | 3.286 | .1515 | 12.84 | .5918 | do. | do. |
| 101 | Arichat, Isle Madame, Nova Scotia. | 45 30.5 | 61 01.3 | 1881 | Oct. 26. | +23 25.9 | Oct. 26. | 74 43 | Oct. 26. | 3.435 | .1584 | 13.03 | .6009 | do. | do. |
|  | Halifax, Nova Scotia. | 44 39.5 | 63 35 | 1881 | .............. | ...... | Nov. 2. | 74 29 | Nov. 2. | 3.459 | .1595 | 12.93 | .5962 | do. | do. |
| 102 | Yarmouth, Nova Scotia. | 43 49.9 | 66 07.2 | 1881 | Nov. 7, 8. | +17 49.4 | Nov. 7. | 74 35 | Nov. 8. | 3.474 | .1602 | 13.07 | .6026 | do. | do. |
| 103 | Weymouth, Nova Scotia. | 44 24.4 | 65 59.8 | 1881 | Nov. 11. | +18 43.4 | Nov. 10. | 74 45 | Nov. 10. | 3.461 | .1596 | 13.16 | .6068 | do. | do. |
| 104 | Annapolis, Nova Scotia. | 44 44.5 | 65 31.1 | 1881 | Nov. 14, 15, 16. | +19 26.8 | Nov. 14, 15. | 74 53 | Nov. 14, 15. | 3.428 | .1581 | 13.14 | .6062 | do. | do. |
| 105 | Windsor, Nova Scotia. | 44 59.6 | 64 08.4 | 1881 | Nov. 22. | +20 42.3 | Nov. 21. | 74 49 | Nov. 22. | 3.423 | .1578 | 13.07 | .6025 | do. | do. |

### ALABAMA.

1. *Fort Morgan.*—The station is 1200 feet northeast of the main station, the latter being on the northwest bastion of the fort.

2. *Montgomery.*—The station is near the northeast corner of Capitol square, and is marked by a marble post sunk flush with the surface of the ground, and inscribed with the letters U. S. C. S. The geological formation is a deep-red clay, covered with rich, black loam 1 to 2 feet deep.

3. *Mobile.*—The station is in the public square, 210 feet north of the position of the transit in the astronomical observatory. The surface of the ground consists of white sand; water at a depth of 4 or 5 feet.

4. *Lower Peach Tree.*—The station is 47 meters due north of the longitude station at this place. The geological formation is red clay, covered by a light, sandy soil to the depth of 6 inches.

5. *Eufaula.*—The station is near the west side of Forsyth street, a few meters north of Washington street, and 594 meters due south of the Coast Survey longitude station. The geological formation is red clay, covered with a light, sandy soil to the depth of 2 feet.

6. *Florence.*—The station is on the northern abutment of the railroad bridge across the Tennessee River at Florence. The station of 1881 is in the grounds of the Synodical Female College, and is marked by a post sunk even with the ground. The formation is limestone.

7. *Indian Mountain.*—The station is about one-half mile south and two miles east of the triangulation point.

8. *Decatur.*—The station is in the open lot across the street from the Polk House. It is marked by a post sunk even with the ground.

### ALASKA TERRITORY.

1. *Sitka.*—The station of 1867 was about 57 feet east of the old Russian Observatory on Japonski Island. The station of 1874 was on the parade ground, 32.2 meters from the quartermaster's store-house, 23 meters from officers' quarters, 84.3 meters from custom-house. The station of 1880 and of 1881 was on Japonski Island, 31 meters south of the old Russian Observatory, and 16¼ meters from the small house near the observatory.

2. *Kadiak.*—The station is the same as the astronomical station of 1867, at Chagafka Cove.

3. *Unalashka.*—The station of 1867 was a few feet west of the astronomical station of the same year, in Captain's Harbor. The station of 1871 and subsequent years was on the small flat on the north side of the north entrance to Iliuliuk Harbor.

4. *Kohklux.*—The station is 154 feet south of the astronomical station. Iron ore abounds and the soil is full of it.

5. *Chichagoff Harbor.*—The station is 87.5 meters from the flagstaff near the village, which bears S. 27° 4′ E. (magnetic).

6. *Kyska Harbor.*—The station is southwest of the village on the top of the sand bluff. The cross on same bluff is 54.3 meters, S. 40¾° E. (magnetic). Station is 10.3 meters above the water's edge.

7. *Amchitka Island.*—The station is at the mouth of gully in middle of high grassy bluff west of lake on south shore of harbor.

8. *Adakh Island.*—The station is on north point of small islet on the west side of narrow entrance to the large bay. It is nearly due east from the site of an old abandoned village. Height above water's edge about 15 feet.

9. *Atka Island.*—The station is on a slight elevation 20 feet northeast from the northwest corner of the church in the village at Nazan Bay.

10. *Popoff Strait, Humboldt Harbor.*—The station is identical with *Sand Point* triangulation station on the north end of an old raised beach at the end of the sand point, about 8 feet above half-tide level.

11. *Lituya Bay.*—The station is on the grassy part of the spit near a small bunch of trees, the only ones on that part of the spit.

12. *Port Mulgrave.*—The station is on the upper edge of the spit, which falls away to the eastward, close to the edge of the grass. In 1880 the point was marked by a pile of stones.

13. *Port Etches.*—The station is on a narrow neck of gravel connecting a small rocky and wooded knoll with the southeast shore of the harbor, half way between the knoll and the rise of the main shore.

14. *Chirikoff Island.*—The station is on the top of the beach, just west of the first small stream west of the first high, rocky bluff east of the village. It is 580 meters from the mouth of the stream at the village.

15. *Semidi Islands.*—The station is on a flattened rock some distance above but close to the water on the southeast edge of Anowik Island, on the small strait which separates it from Keeleetagikh Island.

16. *Chiachi Islands.*—The station is at the top of the beach near a small rill of water that issues from the shingle.

17. *Chignik Bay.*—The station is midway between the two ends of the spit at the top of the beach, just to the eastward of a clump of alders on the edge of the grassy mound.

18. *N. W. Harbor, Little Koniushi.*—The station is identical with *East Base* triangulation station, 40.5 meters southeast of the astronomical station. It is on the summit of a small knoll, 12.5 meters above high water, and 36 meters from the nearest point of the top of the beach.

19. *Saint Paul Island.*—The station is on the grassy flat, 67.3 meters to the northwest of the astronomical station, in line with the cross on the new church spire and the astronomical station.

20. *Nunivak Island.*—The station is close to the top of the sand beach near its southeastern extremity, 55 feet northwesterly from the astronomical station.

21. *Hagmeister Island.*—The station is on the end of the long gravel spit which makes out from the mainland toward the north end of Hagmeister Island. It is just within the edge of the grassy part of the spit, 40 meters from half-tide level east of it.

22. *Port Moeller.*—The station is on the extremity of the inner spit forming the harbor, just within the edge of the grassy top of the spit.

23. *Kasaan Bay.*—The station is near the salmon fishery of the late Charles Baranovitch, at one of the heads of Kasaan Bay. It is 40 to 50 meters north by east from the house occupied by his family.

24. *Fort Wrangell.*—The station is within the old stockade near the middle of the southwest or shore side. The station of 1881 is directly in front of the middle of the Catholic church and 75 feet distant. It is about 200 feet from the old station.

25. *Poverotni Station.*—The station is at high-water mark on the southern shore of the small cove of which Peril Cape forms the western head.

26. *Marble Bluff.*—The station is at high-water mark on the western shore of Admiralty Island, nearly opposite the entrance to the new harbor.

27. *Near Point Marsden.*—The station is at the top of a shingle beach in a slight indentation in the western shore of Admiralty Island, just south of Point Marsden.

28. *Point Whidbey.*—The station is on a shingle and bowlder beach in a little indentation in the northern shore of the peninsula called Point Whidbey.

29. *Pyramid Island Harbor.*—The station is on the edge of the poplar and willow timber, about 80 or 90 meters from the water's edge. It is south (magnetic) from the western edge of Pyramid Island.

30. *Seduction Island.*—The station is on the southernmost island off Seduction Tongue, on a rocky promontory 50 or 60 feet high, from which a clear view was obtained up and down Lynn Canal.

31. *Hot Springs Bay.*—The station is a short distance from the shore of the cove into which the water from the hot springs runs.

32. *Port Althorp.*—The station is on the crest of a grassy ridge connecting the north and south parts of George Island. It is 8 or 10 feet above high-water mark, and 12¼ meters north of the astronomical station.

33. *Coal (Ugolnvi) Point.*—The station is on the extreme southeast point of the spit, a few feet inside of high-water mark.

34. *Dangerous Cape.*—The station is on the top of the bluff forming the cape, and about 20 feet from its western verge.

35. *Dolgoi Island.*—The station is at the top of a small beach, just within the bluff-head forming the southern extreme of Dolgoi Island, and known as Dolgoi Point.

36. *Belkoffsky Settlement.*—The station is at the top of the beach, at the edge of the small flat in front of the bank on which the town is built. It is about 260 meters N., 24° E. (magnetic) from the flagstaff in front of the house of the Alaska Commercial Company's agent.

37. *Near Cape Lisburne.*—The station is about 3 miles to the east and north from the extreme end of Cape Lisburne, on the east side of a stream which here falls into the Arctic Ocean, and just above the beach, on a small, sandy level.

38. *Sandy Beach, between Point Lay and Icy Cape.*—The station is about 10 miles to the southward of Icy Cape, on the spit or sand bar which lies off the main coast. There are no permanent landmarks. The station is at the top of the beach, or on the edge of the top of the spit.

39. *Near Point Belcher.*—The station is on a flat gravel beach, between a lake or lagoon and the sea. At the eastern end of the lagoon, which is a mile east of the station, the natives have erected a beacon of whalebones. A mile west of the station is a deserted village.

40. *Chamisso Harbor.*—The station is near the end of the small, gravel spit at the eastern end of Chamisso Island, above high-water mark. It is marked by a stake and pile of stones.

41. *Port Clarence.*—The station is on the eastern shore of the low spit called Point Spencer, on the northwest part of a small bight, on whose opposite head were the ruins of some native houses. It is on the level surface of the spit, 28½ meters from the water's edge.

42. *Cove Point, Chernoffsky Bay.*—The station is on the western side of the cove forming the harbor, about 35 meters toward the village from the end of the low, grassy point.

43. *Shukan.*—The station is on the south side of the inlet, about one mile from the entrance. It is about 20 feet from high-water mark, in front of and midway between the two easternmost half-ruined log houses. The soil consists of loam over ashes and gravel. The station is marked by a post and buried bottle.

44. *Howcan Mission.*—The station is at the western end of a level, clear space, just to the eastward of the Indian village of Howcan. It is about 30 feet from the bank, and is marked by a pine post 3 feet high, with a bottle buried at is base on the eastern side. The soil was earth 2 feet deep, then solid stone. About the vicinity are many large bowlders of granitic formation.

### CALIFORNIA.

1. *Point Conception, El Coxo.*—The station is on the flat near the landing at Coxo. It is probably identical with the astronomical station of 1850.

2. *Point Pinos.*—No description filed of station of 1851. Station of 1873 is 169.72 meters from astronomical station of 1851–'52, and bears from it S. 75° 53'.5 W.

3. *San Diego, Point Loma.*—The station of 1851 was the astronomical station at the entrance to the harbor. The station of 1853 and 1872 was on the Playa, 70 feet north of the old barracks, now torn down. The station of 1881 was 20 feet south of that of 1872.

4. *Presidio.*—No description filed of station of 1852. The station of 1871 was 7 feet 8½ inches north, and 27 feet 5 inches east of astronomical station Presidio. The station of 1872 and subsequent years was identical with the astronomical station.

5. *Bucksport.*—The station was 15 feet south of the astronomical station.

6. *San Pedro.*—The station of 1853 was near Sepulveda triangulation station, on the open plain, about 3 miles north of the anchorage. The station of 1881 was on top and close to the edge of the bluff above New San Pedro village; it is about 60 feet above the sea. It was marked by a redwood stick projecting about 3½ feet, and 4 pieces of white marble placed around it.

7. *San Luis Obispo.*—The station is in the little valley of the first ravine west of San Luis Creek, and about 200 feet north of the trestle-work of the railroad. A redwood timber projecting 3 feet marks the place.

8. *Humboldt.*—The station is at the western foot of the bluff, and is marked by a post projecting 3 feet above the ground.

9. *Monterey.*—The station of 1854 was near the barracks of the redoubt, about 150 yards south of the officers' quarters. The station of 1881 was near the ruins of the magazine, the southwest

corner of the building called "officers' quarters" bore N. 84° 48′ E. (magnetic), and was distant 127 feet. It was marked by a pine timber projecting about 4 feet.

10. *Tomales Bay.*—The station is on the line from geodetic station to stove-pipe on Preston's house. The soil rests on coarse granite rock.

11. *Ross Mountain.*—The station is 143 feet from the geodetic station on the line to Sonoma Mountain.

12. *Bodega.*—The station is 679 yards from the geodetic station on the line to the signal on Bodega Rock. It is on the side of the rise from the first gully south of Mr. Gill's house, and is marked by a spruce block 5 feet long and 12 inches in diameter, sunk 2½ feet in the ground, with a copper nail driven in the top.

13. *Santa Barbara.*—The station of 1869 was 1028 yards north-northwest from the geodetic station on the outermost spur of the hill. The station of 1881 was a little west of the long wharf on Burton Mound, near the north end of the Burton House, and 20 feet east-southeast from the pole at Burton Station.

14. *San Buenaventura.*—The station is 700 feet N. 0° 54′.6 W. of the geodetic station, and is marked by a block set firmly in the ground and projecting 3 feet, with a nail driven in the top and branded with the letters U. S. C. S.

15. *Dominguez Hill.*—The station is 54.6 meters from the geodetic station in azimuth 196° 02′.6 from it, or on the line to the sharpest peaked mountain north-northeast of Los Angeles.

16. *Punta Arena.*—The station is on the school-house lot on the crest of the plateau north of the village Arena, and on the west side of the road. Northwest of it, 12 or 15 yards, are two pine trees, the eastern one blazed and marked by a nail. A redwood block with brass screw in top marks the spot.

17. *San Diego, new town.*— The station is near the southeast corner of Ash and Seventh streets, almost on the line of the east side of Seventh. It is 60 feet south and 15 feet 7 inches west of astronomical station of 1871, and is marked by a redwood post, 6 inches square, projecting 3½ feet.

18. *Eureka.*—The station is 39.3 feet south of the astronomical station on the prolongation of the line West Point—Eureka. The spot is indicated by a block of fir planted in the ground and marked on top.

19. *Lake Tahoe.*—No description filed, but point marked on plane-table sheet.

20. *Table Mountain.*—No description filed.

21. *Monticello.*—No description filed. Northeast of trigonometrical station, about 30 or 40 meters distant.

22. *Vaca*—The station bears 12° 39′.3 east of north, and is distant 100.5 feet from geodetic station.

23. *Sacramento.*—The station is in the Capitol grounds, near L street, a short distance east of the Twelfth-street gate. It is marked by a bottle buried two feet deep and a pine stub.

24. *Blue Cañon.*—The station is upon a slight eminence, just above the Central Pacific Railroad track and near the school-house. A bottle buried 18 inches and a large rock with a cross cut in the upper surface mark the place.

### COLORADO.

1. *Denver.*—The station of 1873 was 100.22 meters north of the transit instrument. The station of 1878 was in a large, open lot at the corner of Seventeenth street and Broadway. The soil is principally a black loam.

2. *Colorado Springs.*—The station of 1873 was 161 feet north of the transit instrument. The station of 1878 was in the public square on Tejon street, in the rear of the school-house on Cascade avenue. The soil is black loam mixed with gravel.

3. *West Las Animas.*—The station is the same as that used by the American observers in their observations of the solar eclipse of 1878. The soil is a sandy loam.

4. *North Pueblo.*—The station is in the center of a large open square on Court street, due south of the court-house. The soil is principally sand and gravel.

5. *Greeley.*—The station is on the public school-house grounds, in the large open space east of the building. The soil is a light-gray, sandy loam.

## CONNECTICUT.

1. *Tashua.*—In 1833 no description given; supposed to be identical with geodetic station. The station of 1863 is 392.31 meters northwesterly from the geodetic point; from the stone wall, northerly, 18.05 meters; easterly from copper nail in oak tree, 3.80 meters; southeasterly from copper nail in hickory tree, 7.62 meters; southwesterly from copper nail in hickory tree, 13.94 meters. The point is marked by a hickory stub, into which a copper nail was driven. Observations for dip were also made at a point 50 meters southwesterly from the geodetic station, and upon the top of the hill. The geological formation is micaceous rock, covered to a good depth with light yellow loam and gravel.

2. *New Haven.*—The station of 1844 was at the sill of the door of the college library. Observations for dip were also made at the burial ground. Station of 1848 was at the pavilion.

3. *Stamford.*—The station is in the rear of the Union Hotel.

4. *Norwalk.*—The station is on Judge Isaac's Hill.

5. *Stonington.*
6. *New London.*
7. *Saybrook.*
8. *Sachem's Head.*
9. *New Haven.*
10. *Bridgeport.*
11. *Milford.*
12. *Black Rock.*

The positions of these stations are known only by the latitude and longitude. They are supposed to be near the geodetic stations of the same names.

13. *Fort Wooster.*—The station is identical with the geodetic station.

14. *New Haven, Oyster Point.*—The station of 1848 was in the meridian of Yale College Observatory. The station of 1855 was 37 feet east of the center of Howard avenue, New Haven, and 503 feet from the high-water mark at the foot of the street. The soil is sandy, and apparently contains no iron.

15. *Hartford.*—The station of 1859 was in the new park, about half way between the stone bridge and the bridge leading directly to the railroad depot, and about 100 yards from the river. The geological character is slate and alluvium. The station of 1867 was in the yard next to the garden and house of Mr. Perkins, No. 43 Prospect street, opposite the Athenæum and about 210 meters south of the State House. The geological formation is drift, with large bowlders and trap dikes. The station of 1879 is the same as that of 1859.

16. *Bald Hill.*—The station is near the summit of Bald Hill, 422 feet in a southerly direction from the geodetic station. The geological formation appears to be micaceous ferruginous gneiss.

17. *Box Hill.*—The station is near the summit of Box Hill, about 185 feet in a southwesterly direction from the geodetic station. The geological formation appears to be chiefly mica slate.

18. *Sandford.*—The station is at a point 183 feet 4 inches from the geodetic station, and bearing from it 65° 50′.5 east of south. It is marked by a large hickory stub with copper nail in top nearly in the center of a triangle formed by three similar stubs at distances of 2 feet 9 inches, 2 feet 2½ inches, and 2 feet 2 inches, respectively. The dip was observed at two points: the first about 4 feet east of the magnetic station; the second 176½ feet west of north from the geodetic station. Each point was marked by a small hickory stub driven into the ground, with copper nail in top. The geological formation appears to be diorite, covered to the depth of several feet with loose materials, composed chiefly of small bowlders of sandstone and vegetable loam.

19. *Ivy.*—The station is 52.88 meters northeasterly from the geodetic station. The point is marked by a drill-hole into which a wooden peg is driven.

20. *Wooster.*—The station is at a point 80.8 meters southwesterly from the geodetic station. It is marked by a hickory stub, 18 inches in length, into which a copper nail is driven, and marked with a cross.

## DAKOTA TERRITORY.

1. *Pembina.*—The station is on the hill between the Pembina and Red Rivers, near their junction, and is marked by a post. Distance to Pembina River, 75 yards; distance to Red River, 100 yards. The soil is a black and gray loam.

2. *Jamestown.*—The station is in the open lot between Second street and Pacific avenue and Fifth and Sixth streets. It is marked by a post. The soil is black loam over limestone and gravel.

3. *Bismarck.*—The station is on the open plateau of the Missouri River bottom, about one-fifth of a mile southeast of the Sheridan House, and is marked by a post. The soil is dark gray loam.

4. *Yankton.*—The station is in First street near its intersection with Broadway, and marked by a cedar post. The soil is black loam.

### DELAWARE.

1. *Cape Henlopen.*—No description filed of station of 1843. The station of 1856 is located near the edge of the woods to the south and west of the light-house, which bears N. 57° E. (magnetic), and is distant 1170 feet. It is on the summit of a sand dune, which consists entirely of white sand mixed with broken shells.

2. *Wilmington.*—The station of 1846 coincided with the geodetic station. Station of 1875 was on Poole's croquet ground.

3. *Sawyer.*—The station is about one-fourth of a mile west of the geodetic station.

4. *Fort Delaware.*—The station coincides with the geodetic station.

5. *Bombay Hook.*—The station is about 200 feet from the geodetic station, and in the line from it to Cohansey light-house.

6. *Lewes Landing.*—No description filed.

7. *Dagsborough.*—The station is in the village of Dagsborough, near Indian River, about one-fourth of a mile north of the Pepper Creek Bridge. It is in a field adjoining the hotel and post-office, kept by Mr. Smith. It is in the rear of the hotel, and about 100 yards from it. The soil consists of the same white sand and shells as found on the sea coast of the whole peninsula.

### DISTRICT OF COLUMBIA.

1. *Washington.*—Old Coast Survey Office: The station of 1856, 1858, 1859, 1860 was in a lot adjoining the yard of the Coast Survey building, No. 577 New Jersey avenue, on the slope of Capitol Hill. The distance to nearest corner of said building is 65 feet, bearing from the station southeast by east. The magnetic station is about 61 yards north and 13 yards west of the trigonometrical station. Primitive rock forms the base of Capitol Hill; the gneiss and mica-schist are overlaid by alluvium of considerable thickness. Iron ore occurs in the vicinity of the city, but probably not near the station. The station of 1862–1863 was in the field on the slope of Capitol Hill, back of house No. 577 New Jersey avenue. The geological character is drift, sand, and loam, with large pebbles and bowlders. The soil is ferruginous.

2. *Causten.*—The station of 1851 was 366½ feet west-southwest of the geodetic station, and is on the west side of the Rockville road. It is marked by an oak stub and copper nail. The station of 1855 was identical with the geodetic station, and the station of 1851 was also occupied. The geological formation is quartzose sand, clayish and much discolored by oxide of iron.

3. *Washington.*—Station was near Gilliss' Observatory, northwest of Capitol.

4. *Washington.*—Station located on the Smithsonian grounds, 31 feet east of the magnetic observatory and 268 feet from the southeast corner of the Smithsonian Institution. The soil is clayish; quartz pebbles and rocks are imbedded in it. The diluvial soil rests on river sand. Clay iron ore has been found in the vicinity.

5. *Washington.*—The station is about 162 yards east of the center of the Capitol dome, and 50 yards south of the same. The geological character is the same as described in station Old Coast Survey Office.

6. *Washington.*—Assistant Schott's garden, east of house 201 C street southeast, near Second.

7. *Washington.*—Assistant Schott's garden, rear of house 212 First street southeast, near B street.

### FLORIDA.

1. *Sand Key.*—The station is in the line from geodetic station to West Crawfish Key.

2. *Cape Florida.*—The station is about 1200 yards northwest by west from the geodetic station.

3. *Depot Key.*—No description filed.

4. *Saint Mark's Light-House.*—No description filed.

5. *Dog Island Light.*—Station identical with astronomical station.

6. *Saint George's Island.*—Station same as astronomical station.

7. *Cape San Blas.*—No description filed.

8. *Hurricane Island.*—No description filed.

9. *Cape Sable Base.*—No description filed.

10. *Fernandina.*—The station of 1857 was identical with the geodetic station. The station of 1879 was in the eastern part of the town, on what is known as the Indian Mound. The station was on the level part of the southern end, which is somewhat lower than the central portion. The soil of Amelia Island is chiefly white sand and broken shells.

11. *Pensacola.*—The station of 1858 was identical with the astronomical station in the public square. The station of 1861 was 115 meters northerly from the geodetic station, Barkley No. 2. The geological formation is fine white sand.

12. *Apalachicola.*—The station is 80.4 meters westerly from the geodetic station. The geological formation is fine white sand.

13. *Key West.*—The magnetic observatory, where observations were made from 1860 to 1866 inclusive, was 664.2 meters from the Key West light-house, and in azimuth 105° 04′ 28″ from the same. The station of 1879 was in the grounds of the Army Hospital, in a line with the eastern side of the building and midway between its north end and the north fence of the inclosure.

14. *Punta Rasa.*—Station identical with geodetic station.

15. *Turkey Creek and P. Wright stations.*—No description filed.

16. *Bird Key.*—The station is at the south end of the Key, on the west side of the ridge that forms that part of the island.

17. *Jacksonville.*—The station is on a hill north of the town, about one-eighth of a mile north of the new water works. The soil is sand.

18. *Saint Augustine.*—The station is on the government reservation, in the large open grass-plot northwest of the old fort and north of the old gates.

19. *Enterprise.*—The station is in the rear of the village, on the road to New Smyrna. It is 50 yards east of the fence of Mr. John Saul's yard, and 25 yards north of the road. The soil is sand.

20. *Eau Gallie.*—The station is 216 feet north of the old agricultural college. The surface is sand, subsoil coquina.

21. *Saint Lucie.*—The station is on the beach of Indian River, 295 yards south of Paine's wharf. The soil is sand.

22. *Fort Jupiter.*—The station is on sand beach about three-fourths of a mile southeast of Jupiter light-house. It is 10 feet from mean low water, just east of thicket. The soil is sand.

### GEORGIA.

1. *Savannah.*—The station is on Hutchinson's Island, opposite the city of Savannah, and in range with the steeples of the Exchange and Presbyterian church. It is in a cluster of pine trees within 2½ feet of a tree marked by being burnt. These trees are close to and south of the second embankment. The island is formed of alluvial deposits, is nearly covered with water at high tide, and consists principally of a marshy soil which is very elastic.

2. *Tybee Light-House.*—The station is on a sand hill about 20 yards southwest of the light-house keeper's boat-house. Azimuth to Tybee light center, 351° 30′.3; distance, 278 meters.

3. *Macon.*—The station is 63.4 meters south and 57.3 meters west of center of spire of brick building on the right bank of the Ocmulgee River, and known as the Bibb County Male Academy. The geological formation is red clay, covered to the depth of 9 to 12 inches with a light, sandy soil. About 100 yards west of the station a few gneiss rocks appear.

4. *Skiddeway, North Base.*—The station is on the east shore of Skiddeway Island on the first oyster-shell bank south of Waring's Landing, about 220 meters from the boat-house. The station is marked by a marble post, 2½ feet long and 6 inches square, set in the ground.

5. *Butler.*—The station is on Saint Simon's Island, near the old landing.

6. *Middle Base.*—The station of 1872 was on the line of the Atlanta Base, about 60 meters

southwest of Middle Base and 35 meters from railroad. The station of 1873 was 151¾ meters from Middle Base, in the direction of Stone Mountain, and 137¼ meters from railroad.

7. *Kenesaw.*—The station is in an old deserted field about one-half a mile east of the geodetic station (in azimuth 266° 55′.7).

8. *Sweat.*—The station is at the foot of the mountain 2136.1 meters from geodetic station, and in azimuth 2° 02′.1 from it.

9. *Sawnee.*—The station is on the summit of the mountain, 34.59 meters about east-northeast from the geodetic station. The geological formation is diluvial. The rock is much broken, and there is coarse sandstone upon the top.

10. *Cumming.*—The station is in the northeast part of the town on the land of Mr. McAfee. It is on the line between Sawnee Mountain and the mark used as azimuth mark at Sawnee Station, and is distant from this mark 103.8 meters.

11. *Carnes.*—The station is on a ridge of the mountain on the south side and about half way down. It is 648.2 meters from the geodetic station, and in azimuth 10° 46′.3 from it.

12. *Grassy.*—The station is 40.75 meters from geodetic station, in azimuth 110° 36′.0 from it. Soil rich and black, with granite beneath.

13. *Pine Log.*—The station is 300.3 feet from geodetic station, in azimuth 70° 26′.5 from it.

14. *Skitt.*—The station is on the summit of the mountain, nearly in line from geodetic station to Sawnee. It is 29.76 meters from geodetic station, in azimuth 50° 23′.8 from it.

15. *Currahee.*—The station is near the south end of a ridge which extends about 150 yards southward from the summit of the mountain. Its azimuth from the geodetic station is 356° 46′.7.

16. *Academy.*—The station is in a grove 37.81 meters west of the geodetic station.

17. *Lavender.*—The station is 506.4 meters from geodetic station, in azimuth 64° 24′.3 from it.

18. *Johns.*—The station was near the camp ground, about 2 miles north of the triangulation station. It was in an open field belonging to Mr. Davis.

19. *Du Pont or Lawton.*—The station is in an open lot, belonging to Mr. P. A. Herisant, east of the depot. The soil is sand.

### IDAHO TERRITORY.

1. *Siniaquoteen.*—The station is almost south from and in line with the eastern side of the store-house, and 32 paces from the southeast corner. It is 21 paces from the southwest corner of Richard Fry's store. The dip station is 10.9 meters north of declination station in magnetic meridian.

2. *Lake Pend d'Oreille, landing.*—The station is south and 4 meters from the middle of the only road leading to the landing, on a clear spot at the top of the first steep rise (about 50 feet high) from the collection of houses occupied by the employés of the Northern Pacific Railroad Company. It is marked by the post on which the instrument was mounted. The dip station is on north side of road 8.92 meters from declination station.

3. *Lewiston.*—The station is that used by Lieut. T. W. Symons, U. S. A., on the south side of Montgomery street, west of the Presbyterian church, distant from the northwest and southwest corners, respectively, 11.9 and 10.9 meters. The instrument was mounted on the transit block, which is a section of a tree about 30 inches in diameter. The dip station is 16.6 meters south (magnetic) from declination station.

### ILLINOIS.

1. *Mound City.*—Station is identical with the astronomical station.

2. *Cairo.*—The station of 1865 was identical with the astronomical station. The station of 1877 was on Sixteenth street, near Poplar, and marked by stub with small nail. It is about 490 feet from Assistant Eimbeck's astronomical station, and bears from it 24° west of north.

3. *Springfield.*—The station is in the southeast corner of the grounds of Lincoln monument, 220 yards from the center of the shaft.

### INDIANA.

1. *New Harmony.*—No description filed of station of 1848. The station of 1880 was in the "center common" on Main street, and is marked by a post. The station of 1861 was 125 feet southwest of this point. The soil is black loam.

2. *Vincennes.*—The station is on the large inclosed space in the southwest corner of the Catholic cemetery, west of the city, and is marked by a post. Distance to fence southeast 79½ feet, distance to fence southwest 114 feet. The soil is black clay.

3. *Indianapolis.*—The station is in the fair grounds north of the city. It is within the race-course, distant 178.5 feet from the inner circle on the south side, and marked by a post. The soil is black loam.

4. *Richmond.*—The station is in court-house square, just across Front street from the National Academy station of 1871. It is marked by a post 83.8 feet back from Front street. The soil is black loam.

### INDIAN TERRITORY.

1. *Vinita.*—The station was on the premises of Dr. Trott, but, as the ground was under cultivation, no mark was left to indicate the spot.

2. *Atoka.*—The station is 100 yards due north of the residence of Mr. John Harden, about 500 yards west of the railroad. The soil is sandy.

3. *Eufaula.*—The station is east of the railroad, about 400 yards from it. The soil is black loam.

### IOWA.

1. *Des Moines.*—The station of 1877 is in the garden of Mr. David Secor, on the south corner of Ninth and Sycamore streets. It is marked by an oak stub with galvanized iron tack in its center.

2. *Sibley.*—The station is in the yard of the Sibley House, on the east side of the building, 38 feet from nearest point of building, 90.15 feet from Main street, and 14.1 feet from road at right angles to Main street. It is marked by an oak stub with tack.

3. *Davenport.*—The station is on a piece of land belonging to Mr. McIntosh, opposite and north of the house of Mr. Hermann Block, which is on the southwest corner of Seventh and Scott streets. It is marked by a pine stub with tack.

4. *Keokuk.*—The station is in the grounds of Mr. H. H. Clark, at the west corner of Second and Blondeau streets. Distance from north corner of house, 75.3 feet; from south corner, 68.45 feet.

5. *Dubuque.*—The station is about 10 yards south by west from the National Academy station of 1872, on the property of Mr. I. V. Rider. It is marked by a cedar post. The soil is disintegrated limestone.

### KANSAS.

1. *Lawrence.*—The station is in the grounds of the old University building, and is 184.1 feet south from southwest corner of building, and 15 feet west of the road running through the grounds. It is marked by an oak stub projecting 3 inches above the surface, with an iron nail driven in the top.

2. *Humboldt.*—The station is in a field near and north of the Presbyterian church. The soil is black loam.

3. *Emporia.*—The station is in an open lot northwest of the Welch church on Merchant street, and south of the Topeka and Santa Fé Railroad. The soil is black loam.

4. *Great Bend.*—The station is in the large open square due west of the school-house. The soil is black loam.

5. *Dodge City.*—The station is in the large open government lot, 400 yards north of the railroad and about the same distance northeast of Dodge City Hotel. The soil is black loam.

6. *Sargent.*—The station is 250 yards due north of the railroad, and 150 yards west of the house of Mr. I. F. Hardesty. The soil is composed of sand and an impure magnesian limestone.

### KENTUCKY.

1. *Paducah.*—Station is identical with astronomical station.

2. *Upper Point of Rocks.*—Same as astronomical station.

3. *Twenty-seven Mile Island.*—Same as astronomical station.

4. *Patterson's Landing.*—Same as astronomical station.

5. *Oakland.*—The station is very near the astronomical station, a few feet south of it.

6. *Shelbyville.*—The station is 229.9 feet east of observatory.

7. *Falmouth.*—The station is 786.1 feet due north of the astronomical station, on Coleman's farm.

8. *Hickman.*—The station is the south meridian mark in the southwest corner of the court-house grounds. It is 152 feet 10 inches south of the astronomical station. The soil is a sandy loam.

9. *Mayfield.*—The station is in the southwest corner of the court-house square, over the dressed granite post which marks the south end of the meridian line. The soil is sandy loam.

10. *Madisonville.*—The station is in the southeast corner of the court-house square, and is marked by a sandstone post sunk even with the surface. The soil is sandy loam with a subsoil of limestone.

11. *Leitchfield.*—The station is in the court-house square, over the north meridian mark established by the Kentucky Geological Survey.

12. *Lebanon.*—The station is in the northwest corner of the yard of the Norris Hotel, on Main street, and is marked by a limestone rock extending 4 inches above the surface, with a hole drilled in it. The geological formation is limestone.

13. *Stanford.*—The station is in the northeast corner of the court-house grounds, over a limestone rock sunk even with the surface of the ground, with a cross which marks the northern end of the meridian line. The formation is pure limestone.

14. *Livingston.*—The station is in the south end of the meadow west of Sand Brook Hotel, and is marked by a post sunk even with the ground. The soil is gravelly loam, with horizontal coal seams of bituminous coal.

15. *Cynthiana.*—The station is in the new Protestant cemetery, three-quarters of a mile northeast of the city. It is in the grass plot northeast of the main entrance, in the rear of the keeper's house. A marble post sunk even with the ground, and lettered on top M. W. S., marks the point.

16. *Flemingsburg.*—The station is in the public school grounds, in the meadow southeast of the normal school building. The geological formation is pure limestone. The point is marked by a post sunk even with the ground.

17. *Grayson.*—The station is in the open lot east of the East Kentucky Railroad depot. It is marked by a post sunk even with the surface of the ground. The soil is sandy loam.

## LOUISIANA.

1. *Fort Livingston.*—The station coincides with the geodetic station.

2. *Isle Dernier.*—The station is the same as the astronomical station.

3. *Barrel Key.*—No description filed.

4. *New Orleans.*—The station is 84 feet southwest from the astronomical station in the public square in Basin street, south of Canal street. The point is marked by a stub and copper tack. The geological formation is chiefly sand, covered to the depth of 2 or 3 feet by a rich, black soil, forming a very unstable foundation for observations.

5. *Cubitt.*—The station is 57 meters northwest of the geodetic station, on hard ground. It is marked by a scantling, with copper nail. The ground consists of alluvial soil, blue clay, and is very hard when dry.

6. *Southeast Pass.*—No description filed. The soil is soft, but covered with a thin, hard crust, and the ground trembles with the slightest motion of the observer.

7. *Pass à Loutre.*—The station is on a solid mud lump on the south side of the mouth of the Mississippi River, a few steps from the tertiary station F. It is 1241 meters south and 1705 meters east of Pass à Loutre light-house. The ground vibrates with the motion of the steamers which are continually passing.

8. *Côte Blanche.*—The station is 50 meters south of the geodetic station, and is marked by a square post driven into the ground, with a copper nail to indicate the center. It is on the highest part of the hill of the island. The ground is always solid. The soil consists of brown, compact clay.

9. *New Orleans.*—The first station was in the city park. The second is in a wet pasture in the fair grounds. The station of 1880 is identical with the second.

10. *Magnolia Base.*—No description filed.

11. *Southwest Pass.*—The station is on an island west of Stake Island, about 4 feet above water, overgrown with shrubs.

### MAINE.

1. *Agamenticus.*—The station is in a line from the geodetic station to Isle of Shoals Light-House.

2. *Waterville.*—No description filed.

3. *Mount Independence.*—The station is 65 feet from the geodetic station, in a direction perpendicular to the line to Blue Mountain.

4. *Kittery Point.*—The station is in an inclosure to the east of Mr. R. F. Gerrish's cottages, about the center of the lot. Formation, argillaceous slate.

5. *Fletcher's Neck.*—The station is about 44 yards from the geodetic station. A magnetic mark was set up in range about one-half a mile south-southwest.

6. *Richmond Island.*—The station is in the field south of the house of Dr. Cummings.

7. *Portland, Bramhall or Bowdoin Hill.*—The station was in the grounds of Mr. J. B. Brown, 386 feet from the geodetic station Bramhall Hill. The station of 1863 is on the bluff in front of Mr. Brown's house, near the old magnetic station. It is nearly in range with the city surveyor's mark and Mount Independence stone monument, on the edge of the bluff, in prolongation of central line of the street, and 87 feet from the mark. The station of 1864–'65–'66 was 2.31 yards southwest of Bramhall Hill station. Drift formation, coarse gravel, and stones.

8. *Mount Pleasant.*—The station is 154 feet from the geodetic station, in the direction of Mount Independence. It is marked with a red-oak stub and copper nail.

9. *Kennebunkport.*—The station is about 150 yards north-northwest from the Kennebunkport observatory.

10. *Cape Neddick.*—The station is on the north side of Cape Neddick River, in a field belonging to Mr. James Wyer, south of and near the road leading to the seashore.

11. *Cape Small.*—The station is 154 feet from the geodetic station, and is 0°.27′ east of south from it. It is marked with a white-birch stub and copper nail.

12. *Mount Sebattis.*—The station is in the meadow of Col. H. Marr, 50 yards west of his large barn, and 3100 feet from the geodetic station. The azimuth of the magnetic station from the geodetic station is 168° 35′.7.

13. *Mount Ragged.*—The station is 199 feet north of the geodetic station. The rock in the vicinity of the station is gneiss, impregnated with oxide of iron, and it is probable that the whole mountain has the same geological formation.

14. *Camden Village.*—The station is near the western edge of a birch and fir grove, on land belonging to Mr. Joseph W. Ogier, lying east of the road from Camden Village to Rockport. The station is marked with a white-birch stub. It is about 300 yards from tide-water and 150 yards northeast from the high rock. The rocks in the vicinity are of gneiss.

15. *Mount Harris.*—The station is 209 feet from the geodetic station, and bears from it 74° 18′ west of south. It is marked by a drill-hole in the ledge.

16. *Mount Saunders.*—The station is distant about half a mile from the geodetic station, and bears from it 28° west of south. It is marked by a copper nail driven in a stub 15 inches long, sunk flush with the surface of the ground and resting on a bottle. The soil is a light sand overlying felspathic granite.

17. *Southwest Harbor, Mount Desert Island.*—The station is in the village of Southwest Harbor, near the southern end, in a field belonging to Mr. Joseph Mooze, about 250 yards southeast of his barn. It is marked by a bottle buried 6 inches below the surface. A pole is erected over the bottle. The geological formation is red sienite.

18. *Mount Desert.*—The station is on the summit of Mount Desert, and is on the line from Mount Desert geodetic station to Humpback, at a distance from the former of about 115 meters. It is marked by a drill-hole in the rock. The geological formation is red sienite intersected with veins of quartz and trap dikes of greenstone. Iron ore has been found in several localities on the slopes

of the hills, but none has been discovered in the immediate neighborhood of the magnetic station.

19. *Epping Base, east end.*—Identical with geodetic station.

20. *Calais.*—The station is about 400 feet south of the astronomical observatory. There are several ledges of granite and hornblende not far distant; also many surface rocks of the same material. The station is comparatively free from such rocks.

21. *Bangor, Thomas Hill.*—The station was in range between geodetic station and Mount Waldo, distant 600 feet from the former. The geological formation is argillaceous slate. The station of 1863 is at about the highest part of Thomas Hill, near the intersection of Thomas and Highland streets, at the western corner. Two steeples, one a light and the other a dark brown, in range. Station of 1879 same as in 1863.

22. *Humpback.*—The station is upon the summit of Humpback Mountain, and 46.5 meters north from the geodetic station. The geological formation of the mountain is chiefly granite, intersected by trap dikes. The summit ridge appears to be trap rock with occasional bowlders of granite and sienite.

23. *Howard.*—The station is upon the undulating plain, about 250 meters southwest from the geodetic station. The geological formation is chiefly serpentine rock, with frequent dikes of greenstone running northeast and north-northwest.

24. *Cooper.*—The station is about 49 meters southwest from the geodetic station, and nearly in a line to Mitten Mountain. The geological formation is felspathic granite covered with a light soil.

25. *Eastport.*—The magnetic observatory is in the center of the parade ground at Fort Sullivan.

26. *Portland.*—The station is in the north corner of the open square on the heights directly in front of the observatory, northeast end of the city. The geological formation consists of drift, with rocks of gneiss, sandstone, and granite.

27. *Rockland.*—The station is near the foot of the Commercial wharf, 90 paces to the north of it, on the edge of the bluff facing the harbor. Formation, clay soil, over gneiss rocks.

28. *Belfast.*—The station is situated on a triangular space at the intersection of Bridge and North streets, a short distance west of the toll-gate. The geological formation is limestone with clay.

29. *Bath.*—The station is at the southwest corner of the public park. The geological formation seems to be drift, covering mica slate, and gneiss.

30. *Freeport.*—The station is north of the depot, about 350 feet from the railroad track and on higher ground. The rocks appear to be mica slate.

31. *Harpswell.*—The station is in front of the hotel kept by Mr. Dearborn, near the edge of the rocky bluff, directly off the flagstaff and 38 paces distant. The geological formation appears to be mica slate.

32. *Brunswick.*—Station in rear of medical college buildings, Bowdoin College.

## MARYLAND.

1. *Taylor.*—The station is 54 feet north of the geodetic station, and 6½ feet west of the line from Taylor to Linstid.

2. *South Base, Kent Island.*—The station is 64¼ feet north of South Base station, and is in the base line.

3. *Rosanne.*—The station is 126 feet north of the geodetic station.

4. *Finlay.*—The station is 38½ feet from the geodetic station in the direction of Rosanne. In 1846 the station was 30 feet southwest of the geodetic station.

5. *Osborne's Ruin.*—The station is 57½ feet east of the geodetic station.

6. *Marriott.*—The station is 210 feet from the geodetic station in the direction of Taylor. The station of 1849 was 114 feet southwest of the geodetic station, on the south side of the hill. The hill is of gravel (drift with frequent nodules of ferruginous sandstone).

7. *North Point.*—The station is between the Upper and Lower North Point Lights, Patapsco River.

8. *Bodkin Light.*—The station is 50 feet south of the geodetic station, the latter being about 25 feet east of the Bodkin Light.

9. *Fort McHenry, Baltimore.*—The station of 1847 was within the public grounds, between the hospital and western stable, on a line from the flagstaff to Washington monument. The station of 1856 was near the infirmary, outside of the fort, in an open field. It was 445 meters west and 227 meters north of the flagstaff. The station of 1877 is very near that of 1856. The soil consists of clay and marl mixed with pebbles.

10. *Pool's Island.*—Supposed identical with the geodetic station.

11. *Susquehanna Light.*—The station is in the prolongation of line from the Susquehanna Light to Turkey Point Light.

12. *Kent Island* 1.—No description filed.

13. *Soper.*—The station is 352 feet north and 42 feet east of geodetic station. It is marked with a stub and copper nail.

14. *Hill.*—The station is 331 feet east of the geodetic station, and near the edge of the pine grove.

15. *Webb.*—The station is 685 feet south and 25½ feet east of the geodetic station, and is marked with a chestnut stub and copper nail.

16. *Davis.*—The station is about 200 yards south of the geodetic station.

17. *Oxford.*—The station is identical with the geodetic station. The soil consists of clay and marl, several feet in thickness, overlying sand mixed with marine shells.

18. *Mason's Landing.*—The station is on the south bank and near the mouth of Marshall's Creek. It is 115 feet north of the store-house on the wharf at Mason's Landing. The station is on the salt-water marsh; the soil around the marsh consists of white sand mixed with shells.

19. *Cumberland.*—The station is in an open lot at the corner of Decatur and —— streets. It was marked by a bottle sunk 2 feet with a stub above it and is identical with the astronomical station.

20. *Stabler.*—The station is 232 meters north of the geodetic station. The geodetic station bears 4° 53'.3 west of south. It is marked by a hole drilled in a large quartz bowlder whose top is just level with the surface.

21. *Maryland Heights.*—The station is 43.92 meters northwesterly from geodetic station, and is marked by a stub and copper nail. Azimuth of magnetic station at geodetic station 134° 21'.4.

22. *Calvert.*—The station is 262.2 feet south of the geodetic station.

### MASSACHUSETTS.

1. *Copecut.*—The station is 155 feet from the geodetic station in the direction of Manomet.

2. *Indian.*—The station of 1845 was 96¾ feet east of the geodetic station. The station of 1846 was 615 feet from the geodetic station in the direction of Prospect Hill.

3. *Shootflying.*—The station of 1845 was on the line between the geodetic station and Barnstable Light. Station of 1846 was on the line from geodetic station to Hyannis.

4. *Manomet.*—The station of 1845 was in line between geodetic station and Eel River steeple. The station of 1867 is south of and nearly in the meridian of the geodetic station; distance, 52.1 meters.

5. *Blue Hill.*—The station is on the line between geodetic station and Dedham church.

6. *Fairhaven.*—The station is 671 feet east of New Bedford Fort, and is in a field close to the water's edge.

7. *Sampson's Hill.*—The station is 237.9 feet from geodetic station in the direction of Edgartown spire.

8. *Nantucket.*—The station of 1846 was on the north beach near the edge of the town, and on the astronomical meridian of the observatory on the top of Mr. W. Mitchell's house. The station of 1855 is close to the beach north of Mr. Mitchell's house and nearly in its meridian. It is between Nantucket Harbor Light-House and the two range lights to the westward of it. The geological formation of the island is an argillaceous sand overlying a stratum of clay which rests on gneiss rock; apparently no iron.

9. *Tarpaulin Cove.*—The station is northeast of Tarpaulin Cove Light, and near the south of cove.

10. *Hyannis.*—The station is on the line from geodetic station to Shootflying.

11. *Dorchester or South Boston Heights.*—The station of 1846 was 79 feet to the westward of the geodetic station and in a line forming an angle of 99° 40′.2 with the line from geodetic station to Powderhorn. The station of 1855 was between the reservoir and the Blind Asylum, nearly in same position as in 1846. The soil consists of diluvial clay and sand mixed with pebbles to a depth of 90 feet. The station of 1872 is 248 feet south of the center of the cupola of the Blind Asylum, and 82 feet north of Fifth street, north side. It is also about 75 feet west of the west side of H street.

12. *Nantasket.*—The station is 76 feet east of Nantasket signal, and at right angles to the line from Nantasket to Boston Light.

13. *Little Nahant.*—The station coincides with the geodetic station.

14. *Fort Lee, Salem.*—The station of 1849 was 35.6 feet from the geodetic station, and in a line bearing N. 63° 33′ E. The station of 1855 is in the center of the old Fort Lee, and identical with the geodetic station. The soil consists of a clayish sand overlying granite rocks.

15. *Beaconhill.*—The station of 1849 was 375.9 from the geodetic station, and in a line bearing south 51° 30′ from it. The station of 1859 is on the highest point of the hill, and supposed to coincide with the trigonometrical point of that name. The whole region consists of syenite ledges, rocks, and bowlders.

16. *Annisquam.*—No description in 1849. Station of 1859 is 20 feet south of flagstaff, at the foot of the smaller of two bowlders. Syenite rocks.

17. *Baker's Island Light.*—The station is 292.9 feet from the geodetic station in the direction of Halfway Rock beacon.

18. *Coddon's Hill.*—The station is 167.3 feet from the geodetic station in the direction of Fort Lee.

19. *Plum Island.*—No description in 1850. The station of 1859 is near the Plum Island Hotel. Yellowish sand from syenite.

20. *Thompson.*—The station coincides with the geodetic station. Geological formation, granite rock.

21. *Rockport.*—The station is at Allen's Head, west point of Old Garden Cove, about 45 feet above sea-level. It is about 130 feet from the extreme point of rocks. Geological character, syenite rocks.

22. *Ipswich.*—The station is about 100 feet south and a little west of the Congregational church, and on a rock 16 feet from the street. Geological character, syenite rocks.

23. *Deerfield.*—The station is on the public square, about the middle of the eastern side, 20 feet south of the gate, just outside of the wooden inclosure and 6 feet north of the first elm tree from the gate. The geological formation is red sandstone, with the drift overlying.

24. *Chesterfield.*—The station is on a ledge of granite rock west of the three churches and nearly opposite Taylor's Inn. This rock is a few feet above the level of the road.

25. *Springfield.*—The station is in the center of an open lot on the southeast corner of Chestnut and East Worthington streets. Geological character, drift.

26. *Chatham.*—The station is in range with the two lights, and is 184½ feet south and a little west of the more southern. It is 5 feet north of the fence in the open lot. The ground consists of white sand and pebbles (drift).

27. *Wellfleet.*—The station is on the right side of the road from the hotel to the harbor light, on the top of the first (lower) hill, near the corner of the fence, and about 250 yards from the hotel. The ground consists of white sand and pebbles (drift).

28. *Provincetown.*—The station is on the western slope of the hill behind the Pilgrim House, about half way down. The flagstaff at the town-hall is just in range with the northern edge of the steeple of the hall. The town-hall is about one-fifth of a mile west and 300 feet south of the magnetic station. The ground consists of white siliceous sand, alluvium.

29. *Wachusett.*—The station is near the summit of the mountain, about 93 meters south of the

geodetic station. The geological formation of the mountain appears to be chiefly gneiss with some felspathic granite and loose rocks of talc.

30. *Easthampton.*—The station is in the grounds of the Williston Academy. Distance from northeast corner of Classical Hall, 194.5 feet; from southeast corner of same, 172.8 feet; from northeast corner Chapel Hall, 113.6 feet; from maple tree, marked 2 feet above the ground with three copper nails, near fence east of academy, 70.8 feet.

31. *Nantucket Cliff.*—The station of 1867 is in line from geodetic station Cliff to Great Point Light and distant from Cliff station 62.25 meters. The station of 1875 was in the rear of the yard of Mrs. Maxey, on the edge of the bluff, and is marked by a stub driven in the ground. Station of 1879 same as in 1867.

32. *Vineyard Haven.*—The station is in the grounds of Mr. Stevens, in an open lot in the rear of barn, and is marked by an oak stub.

33. *Cambridge.*—The station is in the large open space on the east side of the observatory yard, just north of the road that enters the observatory on the east. It is marked by a solid cedar stub with copper screw.

### MICHIGAN.

1. *Sault de St. Marie.*—The station occupied by Lieutenant Very is in the vegetable garden of Fort Brady. The station occupied by Subassistant Baylor is in same, 46½ feet east of fence of cemetery and 101 feet south of fence to north. It is marked by a cedar post.

2. *Grand Haven.*—The station is in the county court-house grounds, 58 feet from Franklin street, and is marked by a cedar post. The soil is sand.

3. *Mackinac.*—The station is on the open plateau in the rear of Fort Mackinac, between the fort and what is known as the Laundry's quarters. It is marked by a cedar post. The geological formation is sandstone.

4. *Ontonagon.*—The station is on the sand-flat opposite the town, 455 feet from the light-house and 90 feet from the river. It is marked by a cedar post. The subsoil is black loam.

5. *Kalamazoo.*—The station is the same as that occupied by the United States engineers in 1876, near the middle of the park and south of the west end of the jail. It is marked by a stone set in the ground.

### MINNESOTA.

1. *Minneapolis.*—The station is in the grounds of the State University, and is identical with the astronomical station of 1873.

2. *Brainerd.*—The station is in the center of Sixth street, three squares (about one-fourth of a mile) north of the Northern Pacific Railroad, on the edge of the town. It is marked by a post. The soil is almost pure sand.

3. *Glyndon.*—The station is in the public square surrounded by Partridge avenue, Pleasant street, Eglon avenue, and Main street. It is marked by a post. The soil is black loam.

4. *Fort Snelling Reservation.*—The station is 177½ feet east-southeast of the stone marked "N. W." (boundary stone of reservation). It is marked by a substantial post. The soil is black, sandy loam.

5. *Heron Lake.*—The station is in the center of Ninth street near its intersection with Chapman street, about 125 yards north of the Chapman Hotel. The soil is black, prairie loam.

### MISSISSIPPI.

1. *East Pascagoula.*—Station of 1847-'48 is 43.9 feet north of the geodetic station. The station of 1855 is about 200 yards west-northwest of geodetic station.

2. *Mississippi City.*—The station is identical with the astronomical station. It is situated on a ridge of alluvial sea sand. The adjoining country consists of pine barrens, the soil is a stiff red clay covered with sea sand.

### MISSOURI.

1. *Cape Girardeau.*—Station is identical with astronomical station.

2. *Wittemberg.*—Station is identical with astronomical station.

## NEBRASKA.

1. *Omaha.*—The station of 1869 was in the yard of the house on the northeast corner of Nineteenth and Cass streets. The station of 1877 is in the grounds of the high school, 99.2 feet south by east from the corner of the area stone wall, and 80.6 feet east of plank sidewalk leading to south entrance of building. It is marked by a hickory stub. The station of 1880 is the same as in 1877.

## NEVADA.

1. *Verdi.*—No description filed.

2. *Reno.*—The station is in the southwest corner of court-house yard, 28.8 meters from the corner of the court-house. It is marked by a bottle buried 9 inches deep.

3. *Hot Springs.*—The station is 175.0 meters east of the track of the Central Pacific Railroad, opposite the railroad office. It is marked by a bottle buried a foot below the surface and a pine stub projecting 6 inches.

4. *Rye Patch.*—The station is 67.4 meters from the Central Pacific Railroad track, a short distance north of the railroad office and hotel. It is marked by a bottle buried 2 feet deep and a pine stub.

5. *Winnemucca.*—The station is in the northwest corner of the court-house yard, and is marked by a small earthen jar buried 18 inches deep. The distance from the west fence is 4.77 meters, from the north fence 10.55 meters.

6. *Battle Mountain.*—The station is in the northernmost corner of the Capital Hotel garden, and is marked by a bottle buried 18 inches deep.

7. *Elko.*—The station is in the grounds of the Nevada State University, 70.95 meters from the nearest corner of the building, and 3.83 meters from the north fence. It is marked by a blue-glass bottle buried a foot deep.

8. *Wells Station.*—The station is 13.9 meters in a northeast direction from the northeast corner of the public school building. It is marked by a bottle buried 18 inches deep.

9. *Tecoma.*—The station is about 100 meters south of the Central Pacific Railroad track, and 53.7 meters from Peck's Hotel. It is marked by a bottle buried 18 inches deep and a pine stub projecting several inches.

10. *Eureka* (*Town*).—The station is on Story's Hill, in the western part of the town. It is 15.9 meters from the nearest corner of Story's house, and is marked by a glass bottle and large rock with drill-hole placed over it.

11. *Mineral Hill.*—The station is located on the Eureka and Palisade Railroad, about 5 miles from Mineral Hill Mining Camp. It is 64 meters west of the track, in a line with the north face of the warehouse. It is marked by a bottle and pine stub.

12. *Austin.*—The station is in the northwest part of the town, on a barren hill, just back of Chinatown. It is marked by a buried beer bottle, with a large rock resting upon it even with the surface.

13. *Mount Callahan* △.—The station is 18.60 meters from the geodetic station, in azimuth 14° 12′ east of north.

14. *Eureka* △.—The station is 20.60 meters from the geodetic station, in azimuth 27° 35′.6 east of south.

15. *White Pine* △.—The station is 16.6 meters, south 17° 42′ east from triangulation station.

## NEW HAMPSHIRE.

1. *Isles of Shoals.*—The station is on the south side of the harbor of Hog Island, on a small elevation about 100 yards from the water. There is a road leading to it at the south end of the village. A stone pot was buried 2 feet deep, and a pile of stones placed at the foot of the pole.

2. *Unkonoonuc.*—The direction from the station to the geodetic station is 28° 46′.7 west of south.

3. *Patuccawa.*—The station is 106 feet from the geodetic station, in the direction of Agamenticus.

4. *Gunstock.*—The station is near the summit of the mountain, 110 meters northwesterly from

the geodetic station. The geological formation of the mountain appears to be chiefly felspathic granite intersected by dikes of trap-rock.

5. *Monadnock.*—No description filed.

6. *Troy.*—The station is near the south side of what is locally named the "Old Muster Field," in a northerly direction from the town hall. The geological formation appears to be diluvium.

7. *Gorham.*—The station is at Soldier's Hill, east of tower, one-fourth of a mile from center. Soil, sand and pebbles.

8. *Littleton.*—Station is on rock near Oak Hill House, in direction of high school, and close to "playground" or garden of the hotel.

9. *Hanover.*—The station is on the hill a little north of the observatory. A second station was occupied in 1879, about three-fourths of a mile due west of the first station, on the large open plateau belonging to the scientific department. The point is 250 yards west of the road.

10. *Chesterfield.*—The station is about 1 mile east of the factory village, on Deacon Warren Bingham's premises. It is on top of an isolated bald knob east of dwelling, 12.15 feet (?) west-southwest of Wilde's (formerly surveyor) stone, a large stone with deep, irregular notch cut in it, and southwest of the smaller of two maples.

### NEW JERSEY.

1. *Bergen Neck.*—No description filed.

2. *Mount Mitchell.*—No description filed.

3. *Sandy Hook.*—The station of 1844 was 180 feet due north of position of transit instrument in 1842, and 500 feet from light-house. Renwick's station of same year was 376 meters due east of geodetic station. The station of 1855 was 250 feet nearly due west from the light-house. The Hook consists entirely of dunes of quartz sand. Station of 1873 and 1879 is 551 meters from West Beacon, which bears from the station 16° 20′.5 west of north.

4. *Newark.*—No description filed.

5. *White Hill.*—The station is 13¾ feet from the geodetic station, and bears from it 15° west of south.

6. *Church Landing.*—The station is about a mile above the geodetic station.

7. *Pine Mount.*—Station coincides with geodetic station.

8. *Hawkins.*—No description filed.

9. *Port Norris.*—Station coincides with geodetic station.

10. *Egg Island Light-House.*—The station is about 200 feet from the light-house, and bears 12° west of south from it.

11. *Cape May Light-House.*—The station of 1846 was 208.6 feet from the geodetic station, and in a line bearing 54° 40′ east of south from it. The station of 1855 was about 160 yards to the westward of the light-house, within the inclosure and not far from the beach. The station was near the sand dunes, consisting of quartz and comminuted shells; gravel underlies the sand. Station of 1874 is about south of light-house, 869.5 feet from tower.

12. *Townbank.*—The station is at Price's, near the geodetic station.

13. *Pilottown.*—The station is 239 feet southeast of geodetic station.

14. *Chew.*—Station coincides with geodetic station.

15. *Tuckerton.*—The station is in a lot to the rear of the residence of Judge Tucker (1846).

16. *Old Inlet.*—The station is 40 feet distant and in a line from Old Inlet Signal to Cedar Hummock.

17. *Mount Rose.*—The station is in a clover field in front of the house of Mr. Theodore Hunt, about 500 yards east-northeast from the geodetic station.

18. *Atlantic City.*—The station is in range between the southwest corner of the fence of Absecom Light-House lot and that part of the light-house where the covered-way from the keeper's house joins it. It is 37 feet from the fence corner and 171 feet from the light-house at the point mentioned. The ground consists of white sea-sand and sand dunes.

19. *Barnegat Light-House.*—The station is on the road constructed for carrying materials to the light-house when building; it is on the forty-fifth sleeper from the light-house fence, 8 feet from Mr.

Brown's fence, 47 feet from northwest corner and 67 feet from southeast corner of the same. Distance from the light-house, 574 feet. The ground consists of siliceous white sand, with shells.

20. *Long Beach.*—The station is in range with the old Tucker Island Light-House and the old Long Beach House; it is on the top of the nearest dunes to the old house, and distant 123 feet from the southwest corner of the house. At 234 feet north of station on magnetic meridian the southwest corner of the new house bears east (magnetic) 145 feet. The ground consists of white quartz sand, with shells.

## NEW YORK.

1. *Buttermilk.*
2. *Round Hill.*
3. *Bald Hill.*
4. *Howard.*

} No descriptions given; supposed to be near geodetic stations of same names.

5. *New York.*—Station at Columbia College, old site.
6. *New Rochelle.*—The station is about 100 yards south of the Neptune House.
7. *Port Chester.*—The station is at Sawpit's Steamboat Landing.
8. *Manhattanville.*—The station is at the Lunatic Asylum.
9. *Lloyd Harbor.*—No description filed.
10. *Oyster Bay.*—No description filed.
11. *Greenport.*—No description filed.
12. *Drowned Meadow.*—No description filed.

13. *Sand's Point.*—The station of 1847 was on the line from Sand's Point Light-House to Matinicock Point, at the distance of 123 feet from the center of the light-house.

14. *Flatbush* or *Mount Prospect.*—The station of 1846 was 222.4 feet from the geodetic station, and bore 84° 14′ east of north from it. The station of 1860 was on the southern corner of the reservoir at the outer edge of the coping, and very near the place where the old trigonometrical signal was located. The ground consists of small bowlders and drift.

15. *Cole.*—The station coincides with the geodetic station.

16. *Legget.*—The station coincides with the geodetic station.

17. *Fire Island Light-House.*—No description filed.

18. *New York.*—The station is on Governor's Island, between Fort Columbus and Castle William, on the north side of the covered-way connecting the forts, and in range with Trinity Church steeple and Battery flagstaff. The distance to Fort Columbus flagstaff is about 140 yards. The soil consists of quartzose sand overlying mica slate; no traces of iron.

19. *New York.*—The station is on the north side of Bedloe's Island, about 10 feet from the wall and in range with a high bluff on the right shore of the Hudson and the flagstaff on Ellis Island. The distance to Bedloe's Island flagstaff is about 170 yards; it is nearly due south from the station. The station is on quartz sand.

20. *New York.*—The station of 1855 was within a few feet of the geodetic station, and was located on the summit of the rock at the southwest corner of the receiving reservoir, about 25 feet above the level of the water. The rock consists of gneiss, and appears to be free from ferruginous matter. The station of 1872 was on the central part of the Green, immediately west of the Mall. Distance east from road, 317.4 feet; distance north from walk, 576.5 feet; distance south-southeast from oak tree, 187.2 feet. Station of 1873 was on a flat-topped granite knoll in the center of the north meadow, where Ninety-ninth street and a line midway between Sixth and Seventh avenues would intersect. Station of 1874 is at Mount Saint Vincent.

21. *Greenbush.*—The station is on the Greenbush road, close to the woods and not far from Second street. It is about 1 mile east from the Albany State-house. The soil consists of a clayish sand and marl of a dark-blue color; apparently no iron in the soil.

22. *Cold Spring.*—The station is on a granite bluff on the bank of the Hudson, about 400 feet east of an iron gun which is placed on the top of the bluff. It is about the same distance west of the Hudson River Railroad, and near the depot.

23. *Albany.*—The station of 1858 was 209 feet due south from the center of the transit instrument. The soil is chiefly clay, covered with a rich, black loam 8 or 10 inches deep. The station of 1879 is 55 yards due west of station of 1858; the soil is of the same character.

24. *Fire Island.*—The station is coincident with the west end of Fire Island Base. The ground consists of white quartz sand, with shells.

25. *Sag Harbor.*—The station is on Mulford's Hill, nearly in the center of the old redoubt. It is nearly in range between the old Episcopal church and the old signal at Smith's farm, and is about one-fourth of a mile east of the church. It is also nearly in range with the square-towered belfry and Cedar Island Light. The station is over the higher of two small gneiss ledges.

26. *Bath.*—The station is opposite the post-office in front of the public park, and nearly southwest of the court-house. It is 17½ feet from the wooden inclosure of the park. The geological character is calcareous slate and marl.

27. *Ruland.*—The station is 286.9 feet from geodetic station, and bears from it 56° 37′.8 west of north. The prevailing character of the soil is a sandy loam resting on drift.

28. *West Hills.*—The station is 608.7 feet from geodetic station, and bears from it 21° 02′.6 east of north. The soil is chiefly a sandy loam resting on drift.

29. *Carpenter's Point.*—The station is 230 feet west of observatory. The rocks are flinty limestone, with no indication of iron.

30. *Duer.*—No description filed.

31. *Oxford.*—The station is on the knoll of a hill projecting southward on Elder Ransom's high field, about three-fourths of a mile in magnetic meridian north from depot, between Scott and New streets, directly above Dodge's house. It is marked by a 6-inch square stone post, one edge somewhat defective, and a buckshot battered into drill-hole.

32. *Ithaca.*—Station is on Cornell University grounds, in Professor Fuertes' meridian line.

33. *Potsdam.*—The station is located about one-half mile southwest of depot, on a sloping pasture on Mr. Clarkson's property, north of his private premises and south of the road. The station is over a quartz cake, resembling a sharp ice cake half turned up, with notch chiseled in top. It is about 12 paces north of a large rock, forming part of a stone wall.

34. *Pierrepont Manor.*—The station is one-half mile southwest of village, and is marked by a stone set in Mr. W. C. Pierrepont's pasture south of his land-office and garden, and in his own meridian line.

35. *Clinton.*—The station is in a meadow east of Hamilton College Observatory, and south of the ball ground. A large, thick, elliptic flagstone was buried with the surface at a level with the grass and marked with intersecting lines.

36. *Patchogue.*—The station is situated on the land of Mr. Roe, west of the Ocean House. Distance from fence to eastward, 79 feet, distance from fence to southward, 78 feet.

37. *Far Rockaway.*—The station is marked by a stub driven into the ground in front of the Beach Hotel, on the promontory on the land of Mr. M. McCafferty. It is 75 feet north from corner of fence.

38. *Babylon.*—The station is on the west side of the road that runs directly south from the Episcopal church. Angle between Episcopal church and Fire Island Light, 131° 15′.

39. *West Hampton.*—The station is on a bluff 60 feet west of school-house and 40 feet north of the road.

40. *East Hampton.*—The station is on the land of Mr. Jeffries, on the top of a steep bank, and is 25 feet east and 30 feet south of the fence.

41. *Montauk Point.*—The station is in the grounds of the light-house, and is northeast of it.

42. *Sherburne.*—The station is in the rear of Prof. H. A. Newton's barn, in a lot, and is marked by a peg.

43. *Rouse's Point.*—No description filed.

### NORTH CAROLINA.

1. *Bodie's Island.*—The station is at Station LXXII of base line (7223 meters from south terminus), near the house of Mr. E. B. Midgett.

2. *Stevenson's Point.*—The station is in a line bearing 11° 13′ west of north from the geodetic station.

3. *Shellbank.*—The station is northeast of the geodetic station.

4. *Raleigh.*—The station is 105 feet east and 26.6 feet north of the center of Capitol dome.

5. *Wilmington.*—The station is at a point due north of the transit instrument in observatory, and upon land adjoining Dr. Drune's residence, north side of Market street.

6. *Fort Johnson.*—The station is 89.2 meters in a westerly direction from geodetic station. It is marked by a cedar stub and copper nail. Station of 1874 was 150 feet south of flagstaff.

7. *Portsmouth Island.*—The station is at Northeast Base. No further description given.

8. *New Berne.*—The station is located in the solid brick inclosure of the national cemetery, in the open space to the west of the superintendent's house.

9. *Sand Island.*—The station is 50 yards from geodetic station, and bears from it 64° 35′ west of south.

10. *Beaufort.*—The station is in the open lot in the rear of Miss Davis' boarding-house, 80 yards from the rear of the house and 40 yards from Ann street. The soil is sand.

### OHIO.

1. *South Point.*—The station is the same as the astronomical station, between the Baptist church and the river, on the top of the bluff.

2. *Columbus.*—The station is 271.4 feet north of the transit instrument in Capitol square.

3. *Cleveland.*—The station is in the marine hospital grounds, 181 feet north from the astronomical station.

4. *Cincinnati.*—The station is on the brow of the hill, 281 feet due north of the center of the transit instrument in the new Cincinnati observatory, and is marked by a post and copper screw. The soil is a mixture of clay and loam.

5. *Athens.*—The station is in the grass plot west of the college buildings, and marked by a sandstone post sunk 3 feet in the ground, and engraved on the top with the letters U. S. C. S. and a cross. The soil is a sandy loam.

### OREGON.

1. *Ewing Harbor.*—No description filed.

2. *Koos Bay.*—No description filed.

3. *Astoria.*—The station of 1870 was on the crest of the jutting high bluff in the lot of Mr. John Coe, and about 60 feet above the water. It was 283 meters south and 271 meters east from Astor Point station. The station of 1881 is in the northeast corner of school-house block. It is marked by a block and copper nail.

4. *Portland.*—The station of 1870 was in the northeast corner of the custom-house block, near the corner of Fifth and Morrison streets. The station of 1880 was in a vacant lot just west of the Clarendon Hotel. The station of 1881 is in the grass plot in southeast part of court-house block, 8.81 meters south and 3.73 meters east from the edge of the asphalt walks. A stone block, buried 1½ feet, marks the point.

5. *Jacksonville.*—The station is in the grounds of the public school, 30.8 meters nearly due west from the southwest corner of the building. It is marked by a stub and copper nail. There is also a blazed witness tree 20.25 meters southeast of station, and a stump 13.85 meters northeast of station.

6. *Canyonville.*—The station is in Pine street, between Second and Third streets. There is a clump of small cedars to southward, the largest of which is blazed, and marked with a copper nail, and is distant from station 12.4 meters. The dip station is south of declination station 11.07 meters.

7. *Oakland.*—The station is near the northeast corner of the academy grounds, distant from Third avenue fence 7.23 meters, from Locust street fence 11 meters, from northeast corner of academy building 25.21 meters. The block on which the instrument was mounted was left in place. The dip station was 14.64 meters southwest from declination station.

8. *Eugene.*—The station is in the grounds of the State University, about 80 meters east of north from the eastern end of the building. The magnetic meridian passes over the south corner of the lower step at the east entrance. The block on which the instrument was mounted was left in place. The dip station was south of declination station 23.67 meters in magnetic meridian.

9. *Albany.*—The station is in the southwest part of college square. Distance from west fence in line to chimney on Mr. Monteith's house, 42.5 meters; in line to chimney on main part of Mr. Ellison's

house, 39.0 meters; from south fence in line to chimney on Rev. R. L. Stevens' house, 38.15 meters. The block on which instrument was mounted was left in place. The dip station was 15.53 meters south (magnetic) of declination station.

10. *Salem.*—The station is in what is called Willson's avenue, lying between the State Capitol on the east and the court-house on the west. It is in the line of Cottage street, 3 paces west of the path between the north and south gates. The observing-block was painted white, and left for future use. The dip station is 12.7 meters north (magnetic) from declination station.

11. *Saint Helen.*—The station is identical with triangulation station Lemont, about a mile west from the town.

12. *Umatilla.*—The station is on the south side of First street, a little east of D street, on a small knob composed of sand and bowlders. The dip station was 11.6 meters from declination station, in line to azimuth mark.

13. *Blalock.*—The station is about midway between Mr. W. R. Griffin's house and the railroad track. The observing-block was left to mark the point.

14. *Three-Mile Creek.*—The station is 85 paces north of the top of the north bank, measured in line to the academy building, and 63 paces west of the railroad track, measured in line to the northeast corner of the slaughter-house corral, where it strikes the steep rocky bluff.

### PENNSYLVANIA.

1. *Girard College, Philadelphia.*—The station of 1846 was in a line bearing 54° 55′ east of north from the geodetic station, which is in the center of the marble roof of the college. Station of 1855 was to the northeast of the college building. It was 222 feet from the northeast corner and 369 feet from the southeast corner. Station of 1862 was very near where the magnetic observatory stood in 1840–'45, and nearly in the center of the playground. The station of 1855 was also reoccupied. In 1872 the station of 1862 in the playground was reoccupied. It was 235 feet north of the stone wall, 97 feet from the eastern boundary of the playground, and 340 feet from the western boundary (the playground having been enlarged since 1862). The station of 1877 is on the lawn southwest of the college building, near a weeping-willow tree. Distance to southwest corner of building, 450 feet. Bearing of geodetic from magnetic station, 30° east of north.

2. *Bristol.*—The station is at Professor Vanuxem's, about 2 miles above Bristol, on the Delaware River, and about 300 feet north of the canal.

3. *Yard.*—The station is about 250 yards east-southeast from the geodetic station, in the orchard to the north of Mr. Finnigan's house.

4. *Harrisburg.*—The station is to the right of the eastern entrance to the grounds of the Capitol, 78 feet from the middle of the walk to the building, 29½ feet from the wooden fence, and 165½ feet from the northeast corner of the Capitol. The geological formation is slate and sandstone.

5. *Johnson's Tavern, near Brownsville.*—The station is near the highest part of the hill in a large wheat field in the rear of the tavern, which bears west by south from the station, and is distant about 350 yards. The soil is clay on carboniferous strata.

6. *Erie.*—The station is north of the residence of Mr. James C. Reid, on Seventh street, and east of French street. It is in a vacant lot opposite his house and the large shool-house. The soil is clay and marl.

7. *Williamsport.*—The station is to the northwest of the old academy building, over 160 feet from its nearest corner. From the station the two cupolas to the left of the dark, slate-covered spire are in range. The soil is clay with lime and sandstones.

8. *Bethlehem.*—The station is in a field nearly fronting Lehigh College observatory.

### RHODE ISLAND.

1. *McSparran.*—The station is on the summit of the hill in a field opposite to the angle of the roads to Kingston and Wickford.

2. *Spencer.*—The station is about 200 feet north of the geodetic station.

3. *Beaconpole.*—The station is 39.5 feet north of the geodetic station.

4. *Point Judith.*—The station is on the line joining Point Judith Light-House and Beavertail Light-House at the distance of 290 feet from the former.

5. *Watch Hill.*—The station is identical with the geodetic station.

6. *Providence.*—The station is in the grounds of Brown University directly east of the center building and 198 feet from the door. The geological formation is principally quartz rocks, mica, schist, and gneiss, containing no iron.

### SOUTH CAROLINA.

1. *Breach Inlet.*—Station of 1849 was on a line bearing 80° 21′.2 west of south from the geodetic station. The station of 1874 was upon a piece of hard, firm, grass-land near Mr. Truesdale's house. It was 149 meters from Fort Marshall (1865) and in a line from it bearing 134° 39.′3 (from south toward west). The station of 1880 is on the grass plot 60 yards from Mr. Truesdale's house.

2. *East Base, Edisto Island.*—The station is on the line from the astronomical station to a single tall palmetto tree which bears 2½′ east of north.

3. *Allston.*—The station is on the summit of a knoll, 34¼ feet northwesterly from the geodetic station.

4. *Columbia.*—The station is 164 feet from the southwest corner and 293 feet from the northwest corner of the new Capitol building.

5. *Port Royal.*—The station is identical with the astromonical station at the southwest end of Saint Helena Island.

6. *Graham.*—The station is 69.6 meters due north of the geodetic station near the bank of Scull Creek.

7. *Beaufort.*—The station is the magnetic observatory 170 feet north of Assistant Boutelle's house, on the corner of Wilmington and Bay streets.

### TENNESSEE.

1. *Clifton.*—Same as astronomical station.

2. *Johnsonville.*—Same as astronomical station.

3. *Fort Henry.*—Same as astronomical station.

4. *Nashville.*—The station is in the grounds of the Vanderbilt University, 319.1 feet from rear entrance to basement of the building and 410 feet from north fence. It is marked by an oak stub with tack.

5. *Bristol.*—The station is in Mr. Jameson's lot on the spot occupied by the eclipse party, and by F. E. Hilgard, in 1873.

6. *Caryville.*—The station is in the vacant lot opposite M. D. Wheeler's house. The soil is principally gravel and bowlders.

7. *Athens.*—The station is in the grounds of the East Tennessee and Wesleyan University, southeast of the building, and is marked by a post. The soil is disintegrated limestone.

8. *Chattanooga.*—The station is in the southeast corner of the large lawn attached to the Staunton House; it is marked by a limestone rock sunk even with the ground with a cross on it. The soil is disintegrated limestone.

9. *Tullahoma.*—The station is in the rear of the Episcopal church and parsonage, 67 feet 10 inches from the nearest point of the former, and 53 feet from the nearest point of the latter. It is marked by a post sunk even with the ground. The soil is disintegrated limestone mixed with gravel.

10. *Murfreesboro'.*—The station is in the grounds of the Union University, west of the south end of the building, and is marked by a post sunk even with the ground. The geological formation is limestone.

11. *Columbia.*—The station is in the grounds of the Episcopal Institute for females, near the west entrance, and is marked by a post sunk even with the ground. The geological formation is pure limestone.

12. *Pulaski.*—The station is in the grounds of the Martin Female College, and is marked by a post sunk even with the ground. The geological formation is limestone.

13. *Grand Junction.*—The station is in a grove of oak trees northwest of the railroad depot, 31 feet south of oak tree marked with cross, 35½ feet east and 42½ feet west of two trees similarly marked. A cedar post is driven at the point. The soil is sandy loam.

14. *Jackson.*—The station is in the southwest corner of the court-house grounds, 25 feet north of Baltimore street, and 25 feet east of Market street. A post sunk even with the ground marks the point. The soil is sandy loam.

15. *Rutherford.*—The station is in the center of Main street, in the rear of the Corley Hotel, 168 feet from its southwest corner. An oak post sunk even with the ground marks the point. The soil is sandy loam.

### TEXAS.

1. *Dollar Point.*—The station of 1848–'68 was 188 feet south and 15½ feet east of the geodetic station. It was marked by a cedar stake, with copper nail. The station of 1878 is in the open lot due south from Col. Guy M. Bryan's former residence. It is 327 yards south of magnetic station of 1848–'68.

2. *East Base*, *Galveston Island.*—The station is 236.5 feet in a northeasterly direction from the geodetic station, about half a mile from the Gulf beach.

3. *Jupiter.*—The station is 294.3 feet north northeasterly from the geodetic station.

4. *Rio Grande* (*mouth*).—No description filed.

5. *Lavaca.*—The station is 90.5 feet southwesterly from the geodetic station. It is marked by a yellow-pine stub, with copper nail. The soil is rich prairie loam over sand and shells.

6. *Austin.*—The station of 1872 was about 400 feet due north of astronomical station. The station of 1878 was identical with the astronomical station of 1872.

7. *San Antonio.*—The station is in the United States arsenal grounds, upon a solid stone in the rear of the office of the commanding officer, in a large, open space, well removed from all disturbances.

8. *Hempstead.*—The station is in an open field, about 400 yards from the depot, southwest of the Sloan Hotel.

9. *Groesbeck.*—The station is in an open field southwest of Burkley Hotel, about 500 yards from station.

10. *Fort Worth.*—The station is in a lot on First street, in the rear of the residence of Mr. N. M. Maben, in the northwestern part of the city.

11. *Sherman.*—The station is in an open lot due west of the Binkley Hotel, on Pecan street.

### UTAH TERRITORY.

1. *Salt Lake City.*—In 1869 three points were occupied. Station No. 1 was 259 feet north ot the astronomical station; No. 2 was about 100 feet west of the astronomical station, and No. 3 was 443 feet northwest of station No. 1.

The station of 1878 was at a point 75 yards south of Fourth South Temple street and 50 yards east of Second East Temple street. The station of 1881 is near the telegraph longitude station in the southeast corner of the Temple block. It is marked by a granite post set over a bottle, forming also the south end of a short meridian line. The soil is loam.

2. *Castle Rock.*—The station is 350 yards south of Station House. The soil is a sandy loam, intermixed with bowlders.

3. *Ogden.*—The station is in the large open valley due north of the depot, and 400 or 500 yards distant. The soil is a rich, black loam.

4. *Kelton.*—The station is in the northwest corner of a vacant lot in the western part of the town, nearly opposite the Central Pacific Railroad turn-table. It is marked by a bottle buried 18 inches deep.

5. *Corinne.*—The station is in the western part of the town, and south of the Central Pacific Railroad. It is 30.00 meters from the northwest corner, and 33.63 meters from the northeast corner of the Presbyterian church. It is marked by a bottle buried 15 inches deep.

### VERMONT.

1. *Burlington.*—The station of 1855 was about 12 feet southwest of the flagstaff in the center of the camp ground. The soil consists of diluvial clayish sand, 60 or 80 feet deep, overlying lime and sand stone. Station of 1873, no description filed.

2. *Rutland.*—The station of 1859 was in the center of an open lot immediately adjoining the bank building, and south of it. It is in the vicinity of the new post-office. Soil, alluvium, limestone, and slate. Station of 1873 and 1879, no description filed.

### VIRGINIA.

1. *Petersburg.*—The station is 347½ feet from the geodetic station (Roslyn), and is 17° 41′ west of north from it. The hill is composed of drift, with several feet of clay on top. The spring water is strongly impregnated with iron.

2. *Snead.*—The station is in the yard of Mr. Snead, 153 feet from the geodetic station, and bears from it north 70° west. The soil consists of white sand, mixed with shells.

3. *Joynes.*—The station is 1130 feet from the geodetic station, the latter bearing from the magnetic station north 42° 56′ east. The station is on the edge of the salt-water marsh. The soil consists of marsh, hardened by admixture of white sand.

4. *Scott.*—The station is close to the bay, 18 feet west of the geodetic station. Near the station the soil is marshy; elsewhere it is white sand resting on clay.

5. *Cape Charles.*—The station is 2¼ feet from the geodetic station, and directly in line with Smith's Island Light-House. It is on low ground, overflowed at high tides. The soil is white sand, mixed with broken shells.

6. *Old Point Comfort Light.*—The station is between the light-house and the beach, and close to the latter, not far from the wharf with stone piers. It is 233 feet south of the light-house. The soil is white sand, mixed with shells.

7. *Norfolk.*—The station is north and a little west of the city-hall, and is in Mr. Lewellyn's yard, not far from the gas factory, on Smith's Creek. The city-hall is distant 1,250 meters, and bears south 10° 29′ east. The soil is sandy.

8. *Norfolk.*—The station is south and east of the city-hall, in the center of a large open lot between Main and Water streets, not far from Higgins' wharf and the railroad freight depot. The city-hall is 426 meters north and 299 meters west of the station. The soil is sand and river deposit.

9. *Cape Henry Light-House.*—The station of 1856 was between the light-house and the beach, on top of a small sand dune. The light-house is 700 feet distant, and bears south 26° 50′ west. The beach consists of white sand and broken shells. The dip-station of 1874 is 891.5 feet from the light-house, and bears from it north 25° 38.′3 east. The magnetometer occupied a position 68 feet from the dip-station, a little south of east.

10. *Fredericksburg.*—The station is on Brown's Island, in Rappahannock River, close to the bridge. The Episcopal church is distant 301 meters, and bears south 49° 11′.3 west. The surrounding hills consist of loam and gravel.

11. *Richmond.*—The station is nearly due south of the Capitol, on the northwestern extremity of the smaller Mayo Island, east of the bridge over James River. The station is on the surface of the granite rock, a few feet above high-water.

12. *Peach Grove.*—The station is 106.5 meters north of the geodetic station. The soil is gravel and clay.

13. *Wolftrap.*—The station is 100 feet from the geodetic station on the prolongation of the line Wolftrap Light-House to Wolftrap.

14. *Tangier.*—The station is distant from geodetic station 224.16 feet and in azimuth 29° 23′.2 (south to west) from it.

15. *Clark Mount.*—The station is upon the northeast brow of the hill, the point being marked by hole drilled in a small, flat rock. The geodetic station is distant 153.7 meters in azimuth 50° 53′.2.

16. *Bull Run.*—The station is 30.91 meters from geodetic station in azimuth 21° 23.′5 from it. The observations for dip were made in the same line at a distance of 23.3 meters from geodetic station. The mountain consists of broken masses of gneiss, covered with forest growth.

17. *North end of Knott Island.*—No description of position filed. The geological character of the soil was marsh mud overlaid by a stratum of sand about one foot in thickness. Station about one foot above water.

18. *Williamsburg.*—The station is in the grounds of William and Mary College, northwest of the main building. The spire of the college was distant 379.5 feet and bore 50° 44′.6 east of south.

19. *Greenwood.*—The station is on the estate of Dr. J. R. Baylor. It is in the large open grass plot west of his residence, and is marked by a post. The soil is a gravelly loam.

20. *Covington.*—Mr. F. E. Hilgard's station of 1873, in the flower garden in the rear of the McCurdy Hotel, was reoccupied in 1881.

21. *Wytheville.*—The station is in an open grass field about 100 yards southeast of Boyd's Hotel, and south of the railroad. It is marked by a post sunk even with the ground. The geological formation is pure limestone.

22. *Marion.*—The station is in the grounds of the Marion Female College in the lot just west of the main building. It is marked by a post sunk even with the ground. The soil is composed of disintegrated bowlders and gravel. Limestone is the general formation of the country.

### WASHINGTON TERRITORY.

1. *Cape Disappointment.*—In 1851 there were two stations; the first was on the beach where the sand contained iron. A second was therefore taken on the ridge on top of the cape about 45 yards west of the observatory. The first station of 1873 was near the old astronomical station and about 4 feet southeast from the triangulation signal recently erected. The second, or station A, was about 60 feet northward from the northwest corner of the light-house keeper's house. It is marked by a round pine post, about 10 inches in diameter, imbedded in the ground. The station of 1881 is in the northwest corner of light-keeper's yard, 25¾ feet from northwest corner of dwelling, and is marked by a pine post. The soil is light loam.

2. *Scarborough Harbor.*—No description filed of station of 1852. The station of 1855 was at a point of land under the lea of Waddah Island, Nee-ah Bay. The geological formation consists of sandstone and shales of the coal measures. The station of 1881 is about a quarter of a mile east of the church in Nee-ah Indian village, and about 100 feet back from and 15 feet above high water. It is marked by a pine post. The soil is sand with a little loam.

3. *Point Hudson.*—The station of 1856 was on the prolongation of the line Admiralty Head to Point Hudson, and distant from the latter about 170 yards. The station of 1881 is identical with the astronomical station established in 1852 and used in various years subsequently.

4. *Seattle.*—The station of 1871 was near the edge of the bluff bank of Duwamish Bay, to the west of the large white house now occupied by J. Leary, esq. It was about 90 feet south of Jackson street, and marked by a spruce log 8 inches in diameter and 3 feet above the surface of the ground. The soil appears to be free from magnetic sand, but local attraction is suspected.

The station of 1881 is 5.82 meters north of triangulation station Seattle 2. The observing block was left in position, and a stone with drill-hole was buried 1½ feet deep at a point 4.01 meters north of Seattle 2.

5. *Ainsworth.*—The station is on a sand dune 18 feet high, about 60 meters west of the track of the Northern Pacific Railroad and 50 meters southwest of the southern house of the town. The observing post was left to mark the place.

6. *Sixty-Mile Well.*—The station is on the first nearly level portion of the ridge on the west side of the coulée, about 125 meters from the railroad track. From the station the pumping-rod of the wind-mill is seen over and a little east of the west gable of the boarding-house. The dip station was distant 16.65 meters in line to azimuth mark.

7. *Sprague.*—The station is about 125 meters west of railroad track, on a nearly level spot covered with rank grass. Thirty-two paces eastward in line to the middle of the depot is a small mound. Six paces westward is a small ridge with stony surface, and the same distance north is the edge of a small depression 10 meters in diameter. The observing block was left to mark the place. The dip station was 14.55 meters distant in the direction of azimuth mark.

8. *Spokane Falls.*—The station is on the property of Mr. W. M. Wolverton, distant from fence corner to southeast 16.46 meters, and from Railroad avenue 6.32 meters. The observing block marks the point. The dip station was 15 meters north (magnetic) from declination station.

9. *Pomeroy.*—The station was on the lot on the northeast corner of Main and Second streets,

distant from Main-street fence 24.2 meters; from east fence 5.3 meters; from north fence 12.4 meters. The observing post, sawed off within 1 inch of the ground, marks the point. The dip station was 7.55 meters south (magnetic) from declination station.

10. *Walla Walla.*—The station is the same as that occupied by Mr. Clark, of Lieutenant Wheeler's expedition; the brick pier erected by him, on the east side of the court-house block, being used. The dip station was 15.8 meters south of the pier.

11. *Wallula.*—The station is on the north side of the first street north of the old fort, and near an old ice-house. The dip station was distant 10.6 meters, on line to azimuth mark.

12. *Lower Cascades.*—The station is on the farm of Mr. S. M. Hamilton, in the second field southwest from his house, distant 23 paces from fence in line to old barn, and the same from east gate post. It is marked by a post.

13. *Vancouver.*—The station is in the garrison pasture lot south of the old fort, 40 paces from fence in a line to garrison flagstaff, and fifty paces from same fence in line to arsenal flagstaff. The observing block marks the point.

14. *Olympia.*—The station is in the southern part of the block between Union and Eleventh and Columbus and Main streets. It is 35 meters from the southeast corner of the block, and 16.5 meters from south fence, measured in line to chimney on house of Capt. T. J. Brown. The observing block marks the place.

### WEST VIRGINIA.

1. *Clarksburg.*—The magnetic station of 1864 was identical with the astronomical station, being about 100 feet east of the academy. The station of 1880 is in the academy grounds, near the same spot, and is marked by a locust stub and copper tack. The soil is loam and subsoil is soapstone.

2. *Grafton.*—The station is at a point in range with the flagstaff and astronomical station, about a thousand feet northwest of the latter.

3. *Cameron.*—The station is identical with the astronomical station, being directly north of the church, 32.1 feet from northwest corner, and 29.1 feet from northeast corner.

4. *Wheeling.*—The station of 1864 was on the island opposite the Sprigg House, about half-way between the mean level of the river and the picket fence on the east side of the island. The station of 1881 is on the south end of Zane's Island, 225 feet from the Ohio River, and near the center of the proposed race-track. It is marked by a post.

5. *Parkersburg.*—The station is identical with the astronomical station at the foot of Court street, on the bluff above the river bank. The station was re-occupied in 1881.

6. *Point Pleasant.*—The station is identical with the astronomical station north of the bank building, on the bank of the Ohio River.

7. *Charleston.*—The station was identical with the astronomical station, in the vacant lot opposite Mr. Whitaker's residence, on the road leading from ferry. The station of 1881 is in a large vacant lot on the opposite side of the street, one square nearer the Kanawha River. It is marked by a post with copper tack. The soil is sandy loam.

8. *Alderson.*—The station is in the southwest corner of the town, in an open meadow at the foot of a hill on Greenbriar street. It is marked by a post sunk even with the ground. The soil is black loam.

### WISCONSIN.

1. *Madison.*—The station of 1876 was west of the underground magnetic observatory, and was marked by a cedar post about 1 meter in length. The station of 1877 was about 250 feet further south, near Mr. Dinsdale's house. It was marked by a stub, 36 feet from the fence to westward, and 27 feet from the fence toward the avenue.

2. *La Crosse.*—The station is identical with the astronomical station of 1873 in the court-house square.

3. *Madison, Farm.*—The station of 1878 is in the center of the meadow of the university farm, about 1 mile due west of the university. It is marked by a post with copper nail.

4. *Superior City.*—The station is near the center of Fourth street, just east of its intersection with Becker avenue. The soil is black prairie loam.

### WYOMING TERRITORY.

1. *Sherman.*—No description filed.

2. *Cheyenne.*—The station is in the center of a large, open lot, corner of Seventeenth and Dodge streets. The soil is sand and gravel.

3. *Laramie City.*—The station is in a large, open meadow east of the city, between it and the river. The soil is black, moist loam.

4. *Rock Creek.*—The station is in the valley of Rock Creek, southeast of the railroad eating-house. The soil is black loam mixed with gravel.

5. *Fort Fred. Steele.*—The station is 60 yards due south of the United States Army hospital. The soil is gravelly, sandy loam.

6. *Creston.*—The station is on the open plain, 150 yards due south of the point occupied by the American observers of the solar eclipse of 1878. The soil is an alkaline sand.

7. *Point of Rocks.*—The station is about 150 yards south of the railroad station, on the bank of Bitter Creek. The soil is an alkaline sand.

8. *Green River.*—The station is 200 yards due south of the station-house. The soil is an alkaline, white sand.

9. *Carter.*—The station is on the open bottom, 300 yards due east of the station-house. The soil is a sandy loam.

### FOREIGN COUNTRIES.

1. *Quebec.*—The station is about 300 feet south and east of the Wolfe monument, and about midway between the small house and fence opposite, 20 feet from the road. The geological formation appears to be slate.

2. *Montreal.*—The station of 1859 was within the grounds of McGill University. It was 36 feet from the southern gate, and to the right of the road. The station of 1879 is on the opposite side of the road. The geological formation appears to be black slate.

3. *Chamcook.*—The station is near the edge of the wood on the east side of the St. Andrew's road, and about half a mile from the geodetic station. The soil is loam and loose materials.

4. *Aulezavik Island.*—The station is in a direction 33° 57′ west of south from the astronomical observatory of the eclipse expedition, and distant from it 3251 feet. The point was marked by a stake and heap of stones. The rocks are stratified granite of a syenite character.

5. *St. Pierre de Miquelon.*—The station of 1872 was 556.5 feet north of the astronomical station. The station of 1881 is marked by a stone near the middle of the public square, which adjoins the hospital grounds on the north, and is south of the station occupied for longitude in 1872.

6. *San Martin Island.*—The same as astronomical station.

7. *Lagoon Head.*—The same as astronomical station.

8. *Cerros Island.*—The same as astronomical station.

9. *San José del Cabo.*—The same as astronomical station.

10 *Magdalena Bay.*—The same as astronomical station.

11. *Ascension Island.*—The same as astronomical station.

12. *Chatham Island.*—The station is at a point southwest by south from the camp of the Transit of Venus expedition, and about 200 feet from the shore of Whangaroa Bay, at the foot of a low hill, covered with a dense growth of coarse grass and heath. The rocks are basalt and micaceous clay slates, the latter being largely veined with quartz.

13. *Nassau, New Providence.*—The station is 20 feet west-northwest from the granite post marking the southwest corner of the Crown reservation, which extends from the harbor side to the sea side of Hog Island. This post is just above high-water mark, and, looking from the town, is the post nearest to the magazine.

14. *South Bemini.*—The station is on the south shore of the island, 150 yards east of a path cut through mangrove trees leading to the eastern one of two brackish ponds. It is 10 feet from high water. Three glass bottles standing on end are buried 2 feet below the surface. The soil is coral sand.

15. *Water Cay, Salt Key Banks.*—The station is on a flat rock in a valley, about 100 yards from the northwestern part of a small bay in the southern shore of the key.

16. *Matanzas.*—The station is in the circle which forms the eastern end of the public promenade known as La Marina, which extends along the top of the bluff on the northern shore of the harbor from the infantry barracks to the castle of San Severino.

17. *Havana.*—The station is on the roof of the Jesuit College of Belen, on the west side of the room in which the declinometer of the observatory is located.

18. *Bahia Honda.*—The station is on the end of Difuntos Point, 10 feet from high water. It is marked by three bottles buried 2 feet below the surface.

19. *Cape San Antonio.*—The station is on the eastern side of a small bay, 1 mile east of Cajon Point. It is marked by a bottle covered by a pile of broken coral.

20. *Belize.*—The station is in the grounds of the Government House, a few feet back from the sea-wall, and midway between the boat-house and the flagstaff.

21. *Cozumel Island.*—The station is in the southeast corner of the plaza in the village of San Miguel.

22. *Mugeres Island.*—The station is on the northern part of a small, rocky island, the largest of the chain which forms the inner harbor of Mugeres.

23. *Halifax.*—The station is in the center of the large, open plot in the southeast end of the dock-yard. The station of 1881 is identical, as near as could be ascertained.

24. *Perez Island.*—The station is in the center of the island.

25. *Arenas Cay.*—The station is on the east side of the cay, about 70 yards north-northeast from the stone beacon on the south end of the island.

26. *Vera Cruz.*—The station is on the corner of the northeast bastion of the outer line of fortifications of the castle of San Juan d'Ulloa.

27. *Coatzacoalcos.*—The station is on the bluff on the north side of the town in front of the custom-house and half way to the edge of the bluff.

28. *Laguna de Terminos.*—The station is half way between the theater and the shore line.

29. *Campeche.*—The station is about 40 yards south of the well in the center of the plaza of San Roman, which is outside of the wall on the south side of the city.

30. *Progresso.*—The station is on the west side of the small plaza which is formed by the widening of the street, the continuation of which is the road to Merida. It is two blocks from the large plaza in front of the custom-house.

31. *Victoria.*—The station is at the southeast corner of Fort and Wharf streets.

32. *Departure Bay.*—The station of 1880 was near the end of Dunsmoire, Diggle & Co.'s wharf. The station of 1881 is a little to the east of the middle of Jesse Island, 10 feet above and 50 feet back from high water. It is marked by a pine post. The soil is black loam and soft sandstone.

33. *Plover Bay.*—The station is on the spit, Providence Harbor, near the northern shore of a small cove on the eastern side of the spit.

34. *Big Diomede Island.*—The station is near the bottom of a gully at the southeast end of the island.

35. *Michipicoten.*—The station is in a potato garden near the eastern fence of the Hudson Bay Company's grounds, and quite near the river.

36. *Foot of Long Portage.*—The station is near the foot of Long Portage, Michipicoten River.

37. *Big Stony Portage.*—The station is at the upper end of the portage.

38. *Sandy Beach, Dog Lake.*—The station is in front of the camp on the sand beach, one-fourth to one-eighth of a mile north of Pine Point, in Mud Lake.

39. *Fairy Point.*—The station is on the east side of the peninsula jutting south into Missinaibi Lake.

40. *Missinaibi.*—The station is at Hudson Bay Company's post.

41. *Twin Portage.*—The station is at the head of the portage.

42. *Kettle Portage.*—No description filed.

43. *Cedar Island.*—The station is on a long, dry sand and shingle bar southwest of Cedar Island, separated from it by a channel 20 feet wide.

44. *Near small falling brook, Moose River.*—The station is on the left bank of the river near a small falling brook.

45. *Moose Factory.*—The station is at Hudson Bay Company's post.

46. *Camp near Gypsum Beds.*—The station is on the left bank of Moose River, a mile or a mile and a half north of the Gypsum Beds.

47. *Long Gravel Bed.*—The station is on a long gravel bed running parallel to and a little distant from the left bank of Moose River.

48. *Storehouse Portage.*—The station is at the head of the portage.

49. *Albany Rapids.*—The station is on the left bank of Moose River, about three-fourths of the way up the Albany rapids, and about one-eighth of a mile north of the Albany branch.

50. *Moose River, just above a small cascade.*—The station is on the left bank of the river.

51. *St. Paul's Portage.*—The station is at the southwest end of the portage.

52. *Foot of Swampy Grounds Portage.*—The station is at the south end of the portage.

53. *Clarion Island.*—The station is on Sulphur Bay, about 250 yards to the left of the landing and about 3 feet above high water. It is marked by a bottle 1 foot below the surface and a pyramid of bowlders 3 feet high.

54. *Socorro Island.*—The station is on the little sandy beach at the landing at the extreme end of Braithwaite Bay.

55. *La Union.*—The station is on the north one of the three points that together make Chiquiriu Point, inside the stockade of the fort and on the northeast end of the parade ground. The point is marked by a bottle sunk 2 feet below the surface.

56. *Acajutla.*—The station is about 500 yards north of the wharf and custom-house, and is marked by a bottle sunk 2 feet and a stub driven over it flush with the surface.

57. *Champerico.*—The station is 70 meters from the flagstaff in front of the commandant's quarters, which bears from the station north 53½° west. It is marked by a bottle sunk 2 feet and a stub driven flush with the surface.

58. *Salina Cruz.*—The station is on the north side of what is called the lagoon; it is 500 or 600 yards north-northwest from the village in a circular space free from trees. Two feet below the surface is heavy quicksand.

59. *Port Escondido.*—The station is north of the landing-place near the well, in a line between a coquillo and a manzanilla tree, 22 feet from the former and 24 feet from the latter. It is 75 yards from the nearest point of the beach. The soil is sandy, with signs of magnetic iron.

60. *Acapulco.*—The station is in the western end of the eastern of two cocoanut groves at the extreme south end of St. Lucia Bay. From the station the gate of Ft. San Diego bears north 8½° east. There are slight traces of iron in the sandy soil.

61. *Isla Grande.*—The station is on the westernmost of two small sand beaches on the north side of the island. It is near the western end of the beach, about 20 feet above high water, and opposite some outlying sunken rocks. The rocks in the vicinity showed traces of minerals, and probably iron abounds.

62. *Manzanilla.*—The station is on the north end of the small plaza next to the custom-house, a little east of the middle. Iron exists in all the surrounding hills.

63. *San Blas.*—The station is on the sand point, about 100 yards from the custom-house, in line between that building and the low, rocky point forming the end of the breakwater. There is some iron in the sand.

64. *Point San Ignacio.*—The station is 650 feet from high-water, between two ridges or sand hills. The Farallon bears from the station 27¾° west of south. The soil contains some iron.

65. *Santa Barbara Bay.*—The station is on the second ridge from the beach, opposite two huts, both in ruins, which lie a quarter of a mile from the beach.

66. *Guaymas.*—The station is east of and close to the Morro Ingles, at the high-water mark of spring tides.

67. *Tiburon Island.*—The station is on Freshwater Bay, at the foot of the first hill, about 300 yards from the beach, with the middle peak of Cape Tepopa bearing north (magnetic).

68. *Rocky Point.*—The station is close under the point, to the eastward about 300 yards from high-water mark. A bottle was buried and covered with a pyramid of stones 3 feet high. The sand showed very slight traces of iron.

69. *Philipps' Point.*—The station is 25 feet west of the supposed former position of the beacon, its place being occupied by a drift-log, raised part way up and braced. The soil is the detritus of the river, heavy clay, through which many sloughs run.

70. *Point San Felipe.*—The station is in the extreme bight inside the point, between the high hills that form the point and the high, round-top hill to the southward. It is on the northern side of a low plain, just inside the beach. The soil is sand and broken shells. A pole, 10 feet long, was planted at the station.

71. *San Luis Gonzales.*—The station is on the north end of the plain which lies south of the first prominent bluff on the mainland after passing San Luis Island from the northward. It is under the hills forming the northern bluff, about 100 yards from the beach and 150 yards from the nearest hill. It is marked by a pole 10 feet long, with a barrel stave fastened on top. The soil is soft loam.

72. *Santa Teresa Bay.*—The station is about 200 yards from the beach, under the last hill in sight from the anchorage, and about 50 feet above the sea-level. A bottle was buried 2 feet deep, and a post set over it projecting 5 feet, painted in black and white stripes, with 20 large granite cobbles piled around the foot. The hills are granite and slate, with some quartz.

73. *Santa Maria Cove.*—The station is about 625 feet from the beach, in the Cañon de Sta. Maria. It is marked by a bottle buried 2½ feet deep, with a mesquite tree placed over it, and three painted strips of wood nailed to the latter. The soil is yellow loam.

74. *Mulege.*—The station is on the little peninsula formed by the sea and the river, and between Colorado Peak and Sombrerito. The surface soil is clay, with coarse, black sand and broken shells a foot below the surface.

75. *Loreto.*—The station is about 250 yards from the beach and 35 yards from the river, and in line between Cape Tinterera and the sharp peak back of the village. The soil is heavy clay, with coarse gravel 3 feet below the surface.

76. *Isle San Josèf, Amortajado Bay.*—The station is at the mouth of and in the dry bed of the "arroya" which runs close under and on the west side of the first hill east of the point and lagoons. A bottle was buried 2½ feet deep, and a mesquite pole projecting 5 feet set over it, with strips of wood nailed to the top. The soil is coarse gravel, washed down from the mountains, and shows traces of iron.

77. *Pichilingue Bay.*—The station is on the south end of the island of San Juan Nepomereino, south 4° east and distant 150 feet from the astronomical station of U. S. S. Narragansett, which is marked by a pile of stones whitewashed. The soil is coarse coral and broken shells.

78. *La Paz.*—The station is on El Mogote, opposite the city of La Paz. It is on the neck formed by Warren Lagoon and the beach toward the city, and is identical with the astronomical station of the U. S. S. Narragansett. The soil is sandy.

79. *Mazatlan.*—The station is in the corral back of the house of J. Kelly & Co., on the corner of La Plaza and Colle de Oro. It is north 20° west (magnetic) from the round well in the south corner of the corral, and 30 feet distant. The soil is sandy, with traces of iron.

80. *Cape San Lucas.*—The station is in the plain back of the beach and in the village. The southeast corner of Mr. Hove's house is 80 feet distant, and bears (magnetically) north 16½° west. The soil is hard, well-packed sand.

81. *Pequeña Bay.*—The station is on the sand-beach at the head of the bay, nearly midway between the red and white bluffs, and at the entrance to a deep ravine, the largest on the bay. The station is distant from the west bluff of the ravine about 100 feet, from the east bluff 150 feet, and from high water 275 feet. The soil is sand and washings from the bluffs.

82. *Point Abreojos.*—The station is just north of the inner point of Ballenas Bay, about 250 feet from high water, and 50 feet south of the shallow, dry bed of a small lagoon. The soil is sand and broken shells, with washings from the hills.

83. *Guadalupe Island.*—The station is on a plain 40 feet high, about 15 cables north of Whaler's Bay, about midway between two houses, one wooden the other stone, and about 800 feet from the water's edge. It is marked by a bottle buried 6 inches deep, and above it a pyramid of broken lava 4 feet high. The island is a mass of volcanic rock, covered with broken lava.

84. *San Geronimo Island.*—The station is on the southern end of the island, about 100 feet west of the astronomical station of the U. S. S. Narragansett. It is marked by a bottle a few inches below the surface, and a monument of stones over it about 3 feet high. The island is of sandstone formation, covered in many places with sand and guano.

85. *Todos Santos.*—The station is on the plain near the landing place, 100 yards from high water, about midway between the small graveyard and the foot of the hills to the westward. It is in line with the white house, the old adobe house, and the new house. The soil is fine, heavy, hard red clay. The station is marked by a bottle 1 foot below the surface and a small monument of stones.

86. *Waddington Harbor.*—The station is on a projecting point on the north side of the harbor about half-way between the bluffs on the east side of Homalko Valley and the north side of Pigeon Valley. It is about 15 feet above and 60 feet back from high water and close by a deserted hut. It is marked by a pine post and buried bottle.

87. *Anchorage Cove.*—The station is on the southwest side of a small cove about half a mile southwest of Anchorage Cove, on a low point making out from the woods. It is marked by a pine post and buried bottle. The soil is black loam and small stones, with bowlders of granite formation scattered near.

88. *Port McLaughlin.*—The station is on the rising ground back of the Indian village, nearly in line between the Hudson Bay Company's trading-house and the residence of the English missionary, and about 125 feet from the former. The soil consists of loose loam to a depth of 18 inches over a bed of lime rock. The station is marked by a post and buried bottle.

89. *Port Simpson.*—The station is on the rising ground at the back part of the garden belonging to the Hudson Bay Company. It is about 200 feet in front of the house of the English bishop. A small fir tree stands about 25 feet northeast from the station. It is marked by a post and buried bottle.

90. *Rose Harbor.*—The station is on the west side of Rose Harbor, Houston Stewart Channel, about 1 mile above Point Catherine. It is just back from the rocks that line the shore and 15 feet above high water. A cedar stump, about 3 feet high, blazed on two sides, marks the place. The surrounding rocks are granite and sandstone.

91. *North Harbor.*—The station is on the beach of the mainland, just opposite Observatory Rock. It is about 10 feet from high water and is marked by a pine post. The soil is gravel and sand.

92. *Friendly Cove.*—The station is on the beach west of Yuquot Point and 200 yards behind Yuquot village. It is about 40 feet above and 50 yards distant from high water. The soil is gravel and loam. The place was marked by a pine post.

93. *Esquimalt.*—The station is on the first projecting point west of Monroe Head, close to and 10 feet above high water. It is marked by a pine post. The rocks are of trap formation, the soil is hard clay.

94. *Twillingate.*—The station is on the land belonging to the Church of England, about 50 yards west of the fence bounding the vegetable garden of the rectory and 75 yards north of the southern fence of the glebe. It is marked by a 5-foot juniper post carved "V., 1881". The soil is rich meadow loam over gravel and sand.

95. *Turnavik.*—The station is a little east from the center of the smallest of the islands composing the group called Offer Turnavik. About 20 yards to the north is a remarkable glacial cut running nearly east and west. The point is marked by a hole 3 inches deep in the hard rock, which is entirely bare of soil. A line from the flagstaff to the northeast corner of the house occupied by Mr. Bartlett and extended 17 paces farther will reach the point.

96. *Grady.*—The station is on an island situated southeast from the mouth of Hamilton Inlet. It is on a level piece of ground having a thin layer of soil over solid rock, 27 paces, north 30° west from the northwest corner of the agent's house. The main flagstaff bears north 1° east (true) and the second staff north 86° west. The point is marked by a hole drilled 10¾ inches in the solid rock.

97. *Nain.*—The station is about a quarter of a mile, north 15° east, from the flagstaff in front of the mission-house, and very near some large bowlders known as Martin's Stein. It is on a shelf of dry, gravelly soil, bordered by a lower marshy strip a few hundred yards in width, on which is a windlass for hauling up boats. It is marked by a juniper post, carved "V., 1881."

98. *Battle Harbor.*—The station is on that one of the Caribou Islands lying north of Battle Harbor, a narrow strait separating from Great Caribou. The point is 35 paces from the northwest corner of "the shop," on a level strip of ground west of the "root-house," and south of the hill on the summit of which is the signal-gun and flagstaff. It is marked by a post carved "V., 1881."

99. *St. John's.*—The station is in a large field in the northwest corner of the grounds surrounding the Government House, 36 feet from the northern and 92 feet from the western fence of the inclosure. A piece of Pictou sandstone marks the spot, with "V., 1881," cut in it. The soil is loam, overlying gravel.

100. *Sydney.*—The station is in part of the glebe of the Church of England, adjoining the grounds of Mr. King and the cemetery of the Church of England, and opposite the Roman Catholic cemetery and the Church of the Sacred Heart. The station is on the highest part of the lot, near the middle, and marked by a post carved "V., 1881."

101. *Arichat.*—The station is in the private grounds of Mr. W. R. Cutler, nearly midway between the Roman Catholic and the Episcopal churches, on the high ground. It is 20 yards north from a covered well, and is marked by a juniper post carved "V., 1881."

102. *Yarmouth.*—The station is in the yard of the Episcopal church, in range with the northeast and southeast corners of the church and with the cross on the Sunday-school and southwest corner of the church. It is marked by a post 7 inches in diameter, carved "V., 1881." The soil is heavy clay and loam, with gravel.

103. *Weymouth.*—The station is on the first level ground back of the Forbes Jones Hotel, in the private grounds of Capt. A. Le Blanc, 142½ feet from the south post of the gate entering the grounds. The line joining the gate-post and the station would run to the eastward or at right angles to the direction of the fence. It is marked by a 9 inch post, carved "V., 1881."

104. *Annapolis.*—The station is very nearly in the center of the old fort, 168½ feet from the middle of the door of the powder magazine and 120 feet from the sallyport. The station-mark is an artificial stone 20 inches square, sunk even with the ground and marked "S. W. V., U. S. C. & G. S., 1881."

105. *Windsor.*—The station is in the northern angle of Fort Edward, near an old well, 78 feet from the nearest point of the block house and 161 feet from the officers' barracks. A 9-inch spruce post marks the spot, with "V., 1881," cut in it. The soil is gravel and loam.

# APPENDIX No. 10.

# METEOROLOGICAL RESEARCHES.

By WILLIAM FERREL.

## PART III.—BAROMETRIC HYPSOMETRY AND REDUCTION OF THE BAROMETER TO SEA-LEVEL.

### CHAPTER I.

### THE THEORY OF BAROMETRIC HYPSOMETRY.

1. The barometric formula for the determination of altitudes given by Laplace, although a great improvement upon all that had preceded it, was not entirely perfect. The vapor correction, included in the temperature correction by means of a modification of the constant in the latter, is only an approximate one, which, in cases of an extremely dry or an extremely moist atmosphere, and in all cases when the temperature is near or below zero of the centigrade thermometer, is erroneous, and this imperfection may at times give rise to considerable error. In the time of Laplace, also, the relative densities of mercury and of atmospheric air were not sufficiently well known to determine the principal constant in the barometrical formula, and it was therefore necessary to resort to another method of determining it. This was done by Ramond by adopting the constant which gave the best agreements between the altitudes given by the formula and those obtained by trigonometry. But the number of observations and of comparisons was so small, and the temperature correction and its annual and diurnal variations were so imperfectly understood then, that the constant which he obtained, and which has been mostly used ever since, was erroneous, except for the summer season and a certain hour of the day, and is not correct, as it should be, for mean annual and diurnal temperatures. After the accurate experiments of Regnault, by which the relative densities of mercury and the atmosphere became better known, and numerous comparisons of the altitudes given by the formula with those obtained by means of the spirit level, it is now known that the constant obtained by Ramond for Laplace's formula is too small. The constant derived from the results of Regnault's experiments cannot be much in error; but still it would be well to have its accuracy corroborated by many more comparisons of altitudes given by it with those obtained directly by means of the spirit-level. But this can only be done where the difference of level of two stations near to each other and differing considerably in altitude has been accurately ascertained, and where the necessary meteorological observations have been made at the two stations.

The greatest uncertainty in barometric hypsometry arises from the imperfection of the temperature correction. In determining the difference of altitude between two stations from observations made at all seasons of the year and hours of the day, it is found that the results vary very much with the seasons of the year and hours of the day, the differences of altitude obtained being generally too great for the warmest season of the year and the warmest part of the day, and the reverse for the coldest season of the year and part of the day. This was first noted by Ramond, and has been confirmed by all subsequent investigators of the subject. It is now well known that these discrepancies arise from the erroneous assumption that the average temperature of the air column, upon which the difference of pressure between the two stations depends, is the average of the observed temperatures of these stations. Much has been done by Plantamour and Rühlman* in Europe, and by Williamson† and Whitney‡ here, in investigating and explaining these discrepancies; but much more is still required in this direction.

Since the time of Laplace the barometric formula has been put into a great variety of forms, without, however, any great improvement in the convenience of its practical applications, but the vapor correction has been introduced more accurately, and the principal constant has been improved. Since the labors of Plantamour and Bauernfiend, and especially of Rühlman, in this direction, there is little room left for any improvement of the mere shape of the formula or of any of the constants contained in it.

The consideration of barometric gradients, in connection with this subject, is somewhat recent, and they have never been taken into account in any regular treatise on barometric hypsometry. It is, however, pretty well understood now that allowance must be made in some way for the effect of these gradients where there is a considerable horizontal distance between the lower and upper stations. It is this part of the subject which especially needs yet further theoretical consideration before corrections for these gradients can be accurately introduced in practical applications of the formula.

2. Barometric hypsometry naturally follows as a regular part of the preceding researches, being based upon the same general principles and equations. From the development of the three small equations (1), Part I, of these researches, with the subsequent addition of a friction term, we have deduced the equations of the general motions of the atmosphere, and of cyclones, tornados, waterspouts, &c., and from this same development we get the equations showing the relation between the differences of altitudes and barometric pressures of any two stations, so that it is not necessary here to go back to first principles to obtain the fundamental equations of barometric hypsometry.

The method adopted at the outset in the preceding researches is completely exhaustive, leaving it entirely impossible for any effect to escape consideration, and hence our equations throughout contain numerous terms, including those showing the effects of the earth's rotation, which had never been taken into account in such investigations. Accordingly our fundamental equations in this branch of the subject, being deduced from the same development, contain likewise many terms, the effects of which have never been considered, and the consideration of which involves the whole subject of barometric gradients. Some of the small terms which, after close examination, were omitted in the theory of the general motions of the winds, and of cyclones, tornados, &c., as being too small to have any sensible effect under any circumstances, are retained in the equations of this part of the researches, not so much because they are regarded as being of importance, as to show hat even here their effects are so small that they might have been neglected.

From equations (12), Part I, by supplying the omitted terms $D_t^2h$ and $F_h$ in the first of these equations, we get

$$\text{(1)} \qquad \log P' - \log P = \int_h \alpha g + \delta$$

in which

$$\text{(2)} \qquad \begin{aligned} \delta = & \int_h \alpha (D_t^2 h + F_h) \\ & + \int_u \alpha (D_t^2 u - \cos\theta\,(2n + D_t\varphi)\,D_t v + F_u) \\ & + \int_v \alpha (D_t^2 v + 2\cos\theta\,(n + D_t\varphi)\,D_t u + F_v) \end{aligned}$$

in which the integrations in the second member must be carried from $h = h'$ corresponding to the lower station to $h$ belonging to the upper station.

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* Die Barometrischen Höhenmessungen. Von Dr. Richard Rühlman. Leipzic, 1870.

† On the Use of the Barometer on Surveys and Reconnaissances; by Maj. R. S. Williamson, Corps of Engineers, and brevet lieutenant-colonel U. S. Army. Professional Papers of the Corps of Engineers, U. S. Army, No. 15. New York, 1868.

‡ Contributions to Barometric Hypsometry: with Tables for Use in California; by Prof. J. D. Whitney, State geologist.

This is the complete fundamental equation of barometric hypsometry as deduced from the developments in the first part of these researches. It differs from the usual equation in containing in addition the term $\delta$, which, it is seen from its expression, contains the effects of the motions and inertia of the atmosphere together with the effects of the earth's rotation, while the usual equation applies only to a state of static equilibrium of the atmosphere.

From (10) and (20), Part I, accenting $g$ in the latter to indicate its value at sea-level and on the parallel of 45°, and putting $a=273°$, we get

$$(3) \qquad \alpha=\frac{1}{g'l\left(1+\frac{1}{a}t\right)(1+f(e))}=\frac{1}{g'l(1+.00366t)(1+.378e)}$$

in which, putting

B = the barometric pressure of the atmosphere,
$b$ = the tension of aqueous vapor contained in it,

we have

$$(4) \qquad e=\frac{b}{\mathrm{B}}$$

If in (3) we suppose that $t$ and $e$ have the same values at all altitudes as at the earth's surface, then $\alpha$ becomes $\alpha'$, and equation (1) above becomes the same as (14), Part I, except the term $f(h)$ in the latter, which represents the effect of variations of $t$ and $e$ with increase of altitude.

The general expression of the force of gravity $g$ in (13), Part I, expressed in terms of the latitude $\lambda$, and of the height $h$ above sea-level, is

$$(5) \qquad g=g'\left(1-\frac{2h}{r}-0.002606\cos 2\lambda\right)$$

The numerical coefficient of $\cos 2\lambda$ introduced here differs considerably from that of (13), Part I, which was copied from Laplace and is now known to be too large. From the recent determination of the figure of the earth by Colonel Clarke,* from pendulum observations, if we put $g_0$ for the value of $g$ at the equator and sea-level, we have

$$g=g_0(1+.005226\sin^2\lambda)=g_0(1+.002613-.002613\cos 2\lambda)$$

whence

$$(6) \qquad g=1.002613g_0\left(1-\frac{.002613}{1.002613}\cos 2\lambda\right)=g'(1-.002606\cos 2\lambda)$$

which is the same as (5) above at sea-level, where $h=0$. From (3) and (5) above we get

$$(7) \qquad \alpha g=\frac{1-\frac{2h}{r}-.002606\cos 2\lambda}{l(1+.00366t)(1+.378e)}$$

in which, it will be remembered, $l$ is the height of a homogeneous dry atmosphere on the parallel of 45°, with a temperature $t=0$.

3. Since the rectangular co-ordinates $h$, $u$, and $v$ in the last number of (1) are entirely independent of one another, the differential elements in the integration, say by mechanical quadratures, can be so taken as to extend the integration from the lower to the upper station by any line whatever, and since in a fluid the pressure is always the same in all directions, we must in every case arrive at the same result. But as friction, which enters into the expression of $\delta$ (2), is an uncertain element of which it is not possible to take account where there are surface currents, it is best to take that line which avoids it as much as possible. For instance, if it were required to determine the difference of altitude between the two stations A and B, Fig. (1), the integration of the second member of (1) might be carried from A to B along some line near the surface of the mountain, or it might be extended vertically from A to C, on a level with B, and then horizontally from C to B.

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* Clarke's Geodesy, page 345.

In the former case it would be necessary to take into account the temperature, or value of $t$, and also of $e$, in the expression of $\alpha$(3), and likewise the friction F, all of which enter into the integral of the second member of (1), but in the latter case it would be necessary to have the values of $t$ and $e$ in the vertical line AC only, since both these in the line BC could be regarded as being constant and having the same value as at C, except very near the station B, where this line comes to the surface of the earth. The value of the friction term F in the first term of the expression of $\delta$ (2), which is that in the direction of the vertical line AC, would be entirely insensible unless there were a local and very rapidly ascending or descending current, and on the line CB it would be very small, since there is little friction except near the earth's surface. On the part of $\delta$ arising from the integration from C to B would depend the barometric gradient at the level of the upper station, and $\delta$ would be equal 0, where there is no gradient.

The temperature along any line near the surface of the mountain would be better known if we had observations at a number of intervening stations than that on the vertical line AC, and even the mean of the two extremes would generally give an average which would be more correct for a line from A to B near the surface than for the vertical line AC. But as the effect of friction cannot be taken into account, and may be large on the line from A to B near the surface, it is best to obtain the temperature, as nearly as can be, on the line AC vertical over the lower station, which may be very different from the temperature on the same level at the surface of the mountain. During the warmest part of the day, especially in the summer season and in clear weather, the air near the surface of mountain sides becomes much more heated than it does at other places on the same level and at a considerable altitude above the surface, and then, it is well known, there are generally strong currents of air along the surface toward and up the side of the mountain, and the friction terms in the expression of $\delta$ become large. In this case the temperature is greater and consequently the pressure of the air column less, but this is exactly counteracted by the friction of the current up the side of the mountain, for relative lightness of the air near the surface gives rise to the ascending current which is accelerated until the friction exactly counteracts the force which produces the current, after which the current remains uniform as long as the temperature and force giving rise to the current remain the same. This excess of temperature, then, near the surface, above that of the air generally at the same level, should not be used unless we could also take into account the equal and counteracting effect of the friction arising from the currents produced by this excess of temperature.

Early in the morning, especially in the winter season and in clear weather, the reverse takes place and the currents are down and from the mountain side. In this case we also have the effect of the friction terms depending upon this current, but their signs are reversed and their effect exactly counteracts that of the increased pressure of the air column arising from diminished temperature. It is well known to hunters, and all who have encamped at night on mountain sides in clear weather, that the current is generally downward during the night, and hence it is usual to put the fires on the lower side of the camp so as to avoid the smoke. Of course, these ascending and descending currents of mountain sides are observable mostly in calm weather, when they are not interfered with, or completely reversed, by the other more general currents of the atmosphere.

4. Neglecting for the present the first term in the expression of $\delta$ (2), which in all practical applications will be shown to be insensible, if we suppose the integrations in the second member of (1) to be carried from the lower station A, Fig. (1), up vertically to the height of the upper station C, and then horizontally to B, we shall have

$$\log \mathrm{P}' - \log \mathrm{P} - \delta = \int_h \alpha g \tag{8}$$

in which the integral must be taken as defined in § 2, and the values of $t$ and $e$ in the expression of $\alpha$ (3) must be those belonging to the vertical line over the lower station. The value of $\delta$ may be regarded as being independent of $h$, since we can neglect the first term in the expression (2), and will depend upon the motions, inertia, &c., of the air at the level of the upper station. It is seen that the value of $\delta$ becomes a small correction to log P, depending upon the gradient of pressure, and if we put

$\triangle$ =to the increase of pressure in the direction of the upper station from the lower, arising from the gradient depending upon $\delta$, we shall have, since $\triangle$ and $\delta$ will have different signs,

$$\log P' - \log (P - \triangle) = \int_h \alpha g \tag{9}$$

If the true temperatures in the vertical were known in this case, this expression would still contain $\triangle$, a quantity which has different values at different altitudes, and has no accurate and known relation to its value at sea-level or the plane of the lower station, so that if even its value were known at sea-level or the lower station, there would still be considerable uncertainty with regard to its value above. The various conditions to be satisfied, both in the general motions of the atmosphere and in those of cyclones and tornadoes, often require the horizontal motions to vary considerably in different altitudes, and hence the value of $\delta$, and the corresponding value of $\triangle$, must be different at different altitudes.

If we suppose the mountain upon which the upper station is placed to be removed and its place to be occupied by air, the barometric and temperature gradients which would exist in this case could be determined, at least approximately, by those of the air surrounding the mountains. This might be done in any special case by means of simultaneous barometric or temperature observations at several stations around the mountain, or even only two stations, if these were in the line connecting the two stations, and not so far apart that the gradients would change sensibly in the intervening space. For annual and monthly averages of barometric and temperature observations, very accurate charts of barometric and temperature gradients for each month and for the year might be prepared for any country where the necessary observations are at hand, and then from these charts the differences of pressure between the two stations at the level of the lower, and also the differences of temperature, could be obtained wherever observations were made for hypsometrical purposes.

If in the preceding expression we suppose the integrations to be carried from the lower station A, Fig. (1), along the horizontal line on the level of that station to the vertical of the upper station and then along that vertical to B, we shall have, by putting $\triangle'$ for the value of $\triangle$ at this level,

$$\log (P' + \triangle') - \log P = \int_h \alpha g \tag{10}$$

in which the integral in the last member must be taken within the same limits as in the preceding case, but the values of $t$ and $e$ in the expression of $\alpha$ (3) must be those in the vertical DB, Fig. (1), of the upper station, in case the mountain were removed. In this case the value of $\triangle'$ can be more readily obtained than $\triangle$ in the former, and the temperature at D can be obtained from the observed temperature at A, Fig. (1), by means of the temperature gradient. There would, however, be in this case the same uncertainty with regard to the temperature at the upper station since we would need the temperature which the air would have, were the mountain with its abnormally heated or cooled surface removed.

For small differences of altitude $\delta$ may be regarded as constant, and then we shall have, regarding $\delta$ as being small,

$$\triangle' = \triangle'' \frac{P'}{P''} = P'\delta \tag{11}$$

distinguishing the quantities of sea-level by two accents. With the value of $\triangle''$ at sea-level, obtained from charts or otherwise, the value of $\triangle'$ at the level of the lower station may be obtained very nearly.

5. Where the upper station is vertically over the lower one the last two terms in (2) vanish and the expression of $\delta$ is reduced to the first term, and we have in this case

$$\delta = \int_h \alpha (D_t^2 h + F_h)$$

Its value then depends upon the inertia of the air in the accelerated or retarded velocities of the ascending or descending currents, and upon the friction between these currents and the surrounding undisturbed atmosphere. If we neglect the friction and consider the former merely, we get by means of (3), in the case of dry air and temperature, $t$, regarded as being constant,

$$\delta=\alpha\int_h \mathrm{D}t^2h=\frac{a}{g'l\ (a+t)}\int ds^2=\frac{a}{a+t}\,\frac{s^2-s'^2}{78332} \tag{12}$$

in which $s$ is the velocity of vertical motion, $s'$ being the value of $s$ at the assumed origin of the integration. If this is the surface of the earth we necessarily have $s'=0$.

From this expression it is seen that $\delta$ is positive in the case of accelerated ascending currents, and hence the difference between P′ and P, as is seen from (1), is increased in such currents by the reaction of the inertia. It must not be supposed, however, that the pressure at the earth's surface under such an ascending current is greater than at surrounding places, for there cannot be an ascending current unless the air of the current is lighter from some cause than that of the surrounding parts, and the diminution of pressure from this cause is exactly equal to the reaction of the accelerated velocity which it gives rise to. In the case of friction the pressure must be a little less at the base of the ascending current, since a part of the force which overcomes the inertia of the accelerated ascending current is spent in overcoming the friction of the surface currents below, which are necessary to supply the draught of the ascending current.

Since the expression of $\delta$ in this case depends upon $s^2$, the result is the same for either ascending or descending currents, since in both cases we must have $s'=0$ at the earth's surface. The direct action, therefore, of the retarded descending current is exactly equal to the reaction of the equally accelerated velocity of the ascending current. But there cannot be a descending current unless from some cause the air of this current is heavier than that of the surrounding parts, and hence in this case the pressure on the earth's surface is increased from both causes.

The effect of accelerated or retarded ascending or descending currents upon the pressure at the earth's surface, or any assumed level at which $s=s'$, is given by (9), in which $\delta$ is given by (12), and the value of P must be that of P′, corresponding to the level where $s=s'$. This effect is in all ordinary cases exceedingly small. If we suppose the velocity at any height to be $s=10^{\mathrm{m}}$ per second, the value of $\delta$ in (12), supposing the lower station to be on the earth's surface where $s'=0$ and that the temperature $t=0$, would be $\frac{1}{783}$, and multiplying this into $760^{\mathrm{mm}}$, supposing this to be the barometric pressure at the earth's surface, we get by (11) $\triangle=0.96^{\mathrm{mm}}$, or less than one millimeter in this extreme case. With a value $s=5^{\mathrm{mm}}$ at the upper station the effect would be only $0.24^{\mathrm{mm}}$. In all cases, therefore, in which observations are made for hypsometrical purposes the effects of vertical currents are insensible.

Where a column of air is ascending or descending without any change of velocity, or where it is first accelerated and then retarded, or *vice versa*, so that we still have $s=s'$, it is seen that it does not affect the difference of pressure between the two stations, since in such cases we have by (12) $\delta=0$.

6. By means of (7) equation (10) becomes

$$\log \mathrm{P}''-\log \mathrm{P}=\frac{k}{l}\int_h \frac{1}{1+x} \tag{13}$$

in which

$$\left\{\begin{array}{l} k=1-.002606 \cos \lambda \\ x=(.00366+.00138e)t+.378e+\dfrac{2h}{r} \\ \mathrm{P}''=\mathrm{P}'+\triangle' \end{array}\right. \tag{14}$$

In the integration of the last member of (13) it is necessary to have $x$ expressed in such a function of $h$ as to make it either completely or approximately integrable. Let us put

$$\left\{\begin{array}{l} \mathrm{H}=h-h' \\ x=x'-(c\mathrm{H}+c'\mathrm{H}^2+\&\mathrm{c.}) \end{array}\right. \tag{15}$$

in which $h'$ and $x'$ are the values of $h$ and $x$ at the lower station where $t$ and $e$ have the values $t'$ and $e'$. This supposes the decrease of temperature and relative proportion of aqueous vapor to be expressed by a convergent series of the forms

$$\left\{\begin{array}{l} t''-t=c_1\mathrm{H}+c'_1\mathrm{H}^2+\&\mathrm{c.} \\ e'-e=c_2\mathrm{H}+c'_2\mathrm{H}^2+\&\mathrm{c.} \end{array}\right. \tag{16}$$

in which $t''$ is the value of $t'$ corrected for the effect of temperature gradient between the two stations.

By means of these equations the last of (14) becomes the same as the last of (15), in which we shall have

$$(17)\qquad \begin{cases} c=(.00366+.00138e)\,c_1+.378c_2+\dfrac{2}{r} \\ c'=(.00366+.00138e)\,c'_1+.378c'_2 \end{cases}$$

In the expressions of these constants the variable $e$ in the very small term of the second order can be regarded as a constant and equal to the mean of its values at the lower and upper stations.

By means of the last of (15) we get from (13)

$$\begin{aligned} \log \mathrm{P}''-\log \mathrm{P} &= \frac{k}{l}\int_h (1-x+x^2+\&c) \\ &= \frac{k}{l}\int_{\mathrm{H}} \Big(1-x'+x'^2+c\,(1-2x')\,\mathrm{H}+(c^2+c')\,\mathrm{H}^2+\&c\Big) \\ &= \frac{k}{l}\Big((1-x'+x'^2)\,\mathrm{H}+\tfrac{1}{2}c\,(1-2x')\,\mathrm{H}^2+\tfrac{1}{3}(c^2+c')\,\mathrm{H}^3+\&c\Big) \end{aligned}$$

This gives, neglecting all terms below the third order,

$$\mathrm{H}=\frac{l}{k}\log\frac{\mathrm{P}''}{\mathrm{P}}\,\frac{1}{1-x'+x'^2+\frac{1}{2}c\,(1-2x')\,\mathrm{H}+\frac{1}{3}(c^2+c')\,\mathrm{H}^2}$$

From the last of (15) we get, by reversing the series,

$$(18)\qquad \mathrm{H}=\frac{x'-x}{c}-\frac{c'}{c^3}(x'-x)^2+\&c$$

With this value of H in the small terms above, of the second and third order, we get

$$\begin{aligned} \mathrm{H} &= \frac{l}{k}\log\frac{\mathrm{P}''}{\mathrm{P}}\,\frac{1}{1-\frac{1}{2}(x'+x)+\left(\frac{1}{3}-\frac{c'}{6c^2}\right)(x'-x)^2+x'x} \\ &= \frac{l}{k}\log\frac{\mathrm{P}''}{\mathrm{P}}\left(1+\tfrac{1}{2}(x'+x)-\left(\frac{1}{3}-\frac{c'}{6c^2}\right)(x'-x)^2-x'x+\tfrac{1}{4}(x'+x)^2\right) \\ &= \frac{l}{k}\log\frac{\mathrm{P}''}{\mathrm{P}}\left(1+\tfrac{1}{2}(x'+x)+\left(\frac{c'}{c^2}-\frac{1}{12}\right)(x'-x)^2\right) \end{aligned}$$

neglecting all terms below the third order. This by means of (14), since when $x$ becomes $x'$, $t$, $e$, and $h$ become $t'$, $e'$, and $h'$, gives, by changing $t'$ to $t''$, for reasons given in § 4,

$$(19)\qquad \mathrm{H}=\frac{l}{\mathrm{M}}\log\frac{\mathrm{P}''}{\mathrm{P}}\left\{1+[.00183+.00035\,(e'+e)]\,(t''+t)+.189\,(e'+e)+\frac{2h'+\mathrm{H}}{r}+ \right.$$
$$\left. .002606\cos\lambda+\left(\frac{c'}{6c^2}-\frac{1}{12}\right)\frac{(t'-t)^2}{273^2}\right\}$$

in which common logarithms are to be used, and M is the modulus of these logarithms. In the last very small term of this expression, only the term depending upon the temperature in the last of (14) has been taken into account.

If we neglect the part of this term depending upon $c'$, we have the expression of H in the case in which the temperature and value of $e$ decrease in proportion to the increase of altitude, for when this is the case $c'_1$ and $c'_2$ in (16) vanish, and hence, from the last of (17), $c'=0$. If we put

$$(20)\qquad c'=\tfrac{1}{2}c^2$$

the last term in (19) vanishes, and we then have the usual barometric formula, which is obtained by regarding $x$, and consequently $t$ and $e$ in the last of (14) as constants, and equal to the means of their values at the lower and upper stations, in the integration of the last number of (13). By the preceding more general and rigorous method the last term of (19) is added to the usual formula. This term, however, is usually very small, and may be neglected unless either $c'$ is very large, or the value of $t'-t$, which may occur in the latter if the difference of altitude of the two stations is great. Where the value of $c'$ is so great in comparison with that of $c$ that the expression of H in (18) is not sufficiently convergent to make the neglected terms below the third order sufficiently small to be neglected, the last term in (19) does not represent accurately the effect of the term in (18) depending upon $c'$, since the neglected terms may be large in comparison with those retained of the third order.

Considering only the term in the expression of $x$ in (14) depending upon $t$, since the others are generally very small in comparison, we get from (17) and (20)

$$c'_1=\tfrac{1}{2}\times .00366\, c^2_1 \tag{21}$$

If, now, we put in the first of (16) $c_1=.005^\circ$, which is its value if the temperature decreases 0.5° for each 100 meters of increase of altitude, we get $c'_1=.0000000458$. With this value of $c'_1$ the last term of the first of (16) gives, if we put $H=2000$ meters, $c_1H^2=0^\circ.18$. Hence the usual formula requires a decrease of temperature very nearly proportional to the increase of altitude, but not strictly so.

7. Since gravity differs with a change of elevation, the barometer does not give the absolute pressure of the air in measures of an invariable unit. It is evident from an inspection of the formula (19) that this unit may be that of any assumed altitude, and hence it is only necessary to reduce the measure at the one station to that of the unit of measure belonging to gravity at the other. Let B′ and B be the observed heghts of the barometer at the lower and upper stations, respectively, corresponding to the absolute pressures P′ and P measured by a barometer acted upon by an unchanged force of gravity. We shall then have, since the measures given directly by the barometer vary inversely, as the force of gravity,

$$\frac{P''}{P}=\frac{B''}{B}\cdot\frac{g'}{g}=\frac{B''}{B}\left(1+\frac{2H}{r}\right)$$

in which $g'$ is the value of $g$ at the lower station, and in which the last form of the second member of the equation is deduced from the preceding one by means of (5), neglecting insensible quantities. Hence, we have

$$\log\frac{P''}{P}=\log\frac{B''}{B}+\frac{2MH}{r}$$

M being the modulus of common logarithms. The last term of the second member being very small, we can substitute for H its approximate value deduced from (19), which is

$$H=\frac{l}{M}\log\frac{P''}{P}$$

With this value of H the preceding equation gives

$$\log\frac{P''}{P}=\log\frac{B''}{B}\left(1+\frac{2l}{r}\right)$$

By means of this expression (19) becomes

$$H=\frac{l}{M}\left(1+\frac{2l}{r}\right)\log\frac{B''}{B}\left\{1+[.00183+.00035(e'+e)](t''+t)+.189(e'+e)+\frac{2h'+H}{r}+.002606\cos\lambda+C\right\} \tag{22}$$

in which

$$C=\left(\frac{c'}{cc^2}-\frac{1}{12}\right)\frac{(t'-t)^2}{273^2} \tag{23}$$

is a small correction to the usual formula to make it strictly applicable where the values of $t$ and $e$ vary with increase of altitude according to the law of (16). Where these vary as the first power of H we have $c'=0$ in the expression of C.

8. The effect supposed to be due to the attraction of the strata of the earth between the upper station and the level of the lower station, introduced into the formula by Rühlman, has been neglected here. This was introduced by him upon the hypothesis that these strata are so much additional attracting matter coming between the upper station and the earth's center, and that consequently the attraction at the upper station, as at B (Fig. 1), is greater than at C on the same level in open space vertically over the lower station. From theoretical considerations alone

it is not probable that there has been much increase of matter between the upper station and the earth's center from the formation of continents, table lands, and mountain ranges, and hence there is little increase of attraction at the upper station from this cause, for the bringing of a part of the attracting strata a little nearer the attracted body has a very little effect, unless it is brought from a great distance beneath.

If the earth was originally fluid, as we have good reason to suppose, the amount of matter then between any point on or above the earth's surface must have been everywhere the same, except so far as it depended upon the earth's ellipticity, the effect of which is taken into account in the formula, and does not enter into the question here. Theories may differ with regard to the manner in which continents and mountain ranges have been formed, but they most probably originated in some way from the gradual cooling and contracting of the interior part of the earth, leaving the external strata too large for the interior, from which cause they were forced up to a higher level at some parts of the surface, with little lateral transfer of matter, leaving the parts below less dense and the amount of attraction on any point above them but little increased.

The sea originally, either as vapor or water, must have been equally distributed over all parts of the earth's surface. The elevation of continents and mountain masses above the general level of the bottom of the sea, displaced that part of the sea which originally existed where the continents now are, and increased the amount of matter where the sea now is, and hence from this cause there has been a decrease in the amount of attraction over the continents and an increase over the sea. There is also much plausibility in Archdeacon Pratt's theory that the inequalities of the earth's surface, as seen in the mountains, plains, and ocean beds, have arisen from unequal rates of cooling and contraction, they being supposed to be greater in the parts covered by the ocean than under the continents, and hence the continents so formed would not imply an increase of matter. But there is another theoretical consideration which must be regarded as completely decisive of the question of the inferior density of the earth's crust, where the continents are, in comparison with that of the part covered by the ocean. The whole globe can be so divided into two hemispheres that nearly all the land is contained in the one, and nearly all the ocean in the other. If the continents and the parts of the earth's crust under them had the same density as the undisturbed strata under the ocean, the center of gravity of the earth would occupy the center of the mass, and the ocean would be drawn over to the side where the continents mostly exist, and leave some parts now covered by the ocean as dry land. There cannot, therefore, be much increase of matter in the parts of the earth's crust where the continents exist.

9. The preceding deductions from merely theoretical considerations are completely confirmed by numerous pendulum observations made over nearly all parts of the globe. If we examine the discussions of these observations in the determinations of the figure of the earth by Airy, Bowditch, and quite recently by Clarke,* it is seen that the residuals mostly indicate diminished gravity on the continents, especially for elevated stations, and increased gravity on small islands in the ocean. It is not to be supposed, however, from this that there is really less matter where the continents are, for these residuals arise mostly from the reductions of gravity to sea-level upon the hypothesis of an increase of matter equal to the mass of the continents above sea-level. The results show that if these reductions were omitted, as they should be according to the preceding view of the matter, the residuals would nearly disappear. This is especially seen in the geodetic operations of India, in which, as the Himalayas are approached, the pendulum observations of the elevated stations, with the usual reductions to sea-level, indicate a great deficiency of gravity. With regard to this Colonel Clarke says: "Kaliana was fixed on by Sir G. Everest as the nearest approach to the base of the Himalayas for reliable geodetic observations, and in our tables we see that at that station and all north of it there is a large defect of gravity, attaining at Moré an amount of—22 vibrations. It is very remarkable that this is precisely the amount of the correction that had been applied for the attraction of the mountains, so that the apparent vertical attraction of the three miles of earth crust between Moré and sea-level is zero. And, in fact, at most of the other high stations the residual discrepancy is diminished or removed if we omit the corrections for the attraction of the table land lying between the station and the sea-level."†

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* Geodesy, by Col. A. R. Clarke, C. B., Royal Engineers, F. R. S., Hon. F. C. P. G., corresponding member of the Imperial Academy of Sciences of St. Petersburg: Oxford, 1880.

† Clarke's Geodesy, p. 350.

It seems, then, not only from the preceding theoretical considerations, but also from actual observations, that the supposed effect upon gravity of table lands and of mountain masses should be neglected, not only in barometric hypsometry, but also in reductions of pendulum observations to sea-level, and it has accordingly been neglected in formula (22).

10. It is now necessary to have the accurate numerical values of the constants $l$, M, and $r$ in (22). Of these, the most important is $l$, which is the height of a homogeneous dry atmosphere at the temperature of 0° under a pressure equal to that of a column of mercury of $760^{mm}$ at the same temperature arising from the force of gravity at sea-level on the parallel of 45°. This is to the height of the mercurial column inversely as the densities of air and mercury under these circumstances. Regnault found the density of mercury equal 13.59593*, that of pure water at the temperature of 4° being unity. At Paris, latitude 48° 50′ and altitude 60 meters, he also obtained for the density of pure air, under the barometric pressure of $760^{mm}$ and temperature 0°, the value .001293187†, the unit of measure being the same as in the case of the mercury. As the density is as the pressure and this as gravity, this density at the earth's surface and on the parallel of 45° would be .001293187 $g':g$. From (5), putting $h=60$ meters and $\lambda=48° \ 50'$, and $r=6367324$ meters (20890548 feet), as obtained by Clarke, we get $g':g=.9996708$, and hence, $.001293187\times.9996708=.00129276$ for the density of pure air at sea-level on the parallel of 45°, and under a pressure of $760^{mm}$ of mercury.

The air in general contains about .04 per cent. of carbonic acid gas with a density of 1.529 compared with that of air. Being heavier than air it increases its density by the $.0004\times.529=.0002116$ part. Hence the density of dry air, such as is generally met with in barometric hypsometry, may be put equal to $.00129276\times1.0002116=.00129303$. With this density of air and the preceding density of mercury obtained by Regnault, we get

$$l=0.76^{m}\times\frac{13.59593}{.00129303}=7991.2 \text{ meters.} \qquad (24.)$$

11. This value of $l$ depends entirely upon Regnault's determinations of the densities of mercury and of air, without regard to other determinations, and differs but little from that used in the preceding parts of these researches. The determinations of Regnault are undoubtedly the most reliable we have, not only because they were made with great care, but also because being for the most part the most recent, the processes of the others were carefully examined and measures were devised to avoid sources of error which, it was thought, might have affected the previous determinations.

The uncertainty in the density of mercury is not great enough to be of much consequence in the determination of this constant, and Regnault's density seems to be about a mean of all that are entitled to much weight. It is very nearly the same as that of a more recent determination which should have great weight. According to Prof. Balfour Stewart,‡ "it has been determined at the Kew Observatory that the weight *in vacuo* at 62° Fahr. of a given volume of purified mercury is to that of the same volume of water in the proportion of 13590.86 to 1001.62 grains." From these, by reducing the former to 0° C. and the latter to 4° C., the density 13.594 was deduced, which differs but little from Regnault's result.

In the density of air the uncertainty seems to be much greater, since the differences between the results of different experiments are much larger, but Regnault's result is entitled to much more weight than the others, and besides it is now generally adopted, so that it is thought best to adopt it here, also, without attempting to determine a more probable density by giving weights to other determinations. If it should be thought by some that the principal constant in the formula, deduced from this density, should be a little different, a proportionate change in the altitudes obtained by means of the formula can be readily made.

12. With the well-known value of M and that of $r$ already given, and the value of $l$ in (24), the expression of H in (22), neglecting the small correction C, is in meters

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[*] Pogg. Annalen der Physik, Band 74, p. 213. [†] *Ibid.*, *p.* 208. [‡] Treatise on Heat, Art. 75.

$$(25)\quad H=18446.6\log\frac{B''}{B}\left\{1+[.00183+.00035(e'+e)](t''+t)+.189(e'+e)+\frac{2h'+H}{6367324}+.002606\cos 2\lambda\right\}$$

$$=18446.6\log\frac{B''}{B}[1+.00183(t''+t)][1+.189(e'+e)]\left(1+\frac{2h'+H}{6367324}\right)(1+.002606\cos 2\lambda)$$

The last form is sensibly the same as the first, and is adapted to computations by logarithms, by which the computations are more conveniently made.

The value of Rühlman's principal constant, with the formula expressed in the form above, is 18429.1. The difference affects the results given by the formula less than the one-thousandth part, and it arises almost entirely from the neglect here, for reasons already given, of the supposed effect of the attractions of table lands and mountains. The value of Laplace's constant is 18336, or, with the formula expressed as above, 18382, which is considerably less than that of (25) above. In the time of Laplace the densities of mercury and of air were not sufficiently well known to determine the value of $l$ from (24), and the principal constant in Laplace's formula was determined from observation. This was done by Ramond in 1803 from barometric and thermometric observations made at Tarbes, France, with the instruments 322 meters above the level of the sea, and from corresponding observations made on the top of the Pic du Midi and other neighboring peaks, with altitudes ranging from that of the Pic du Midi, 2935 meters above sea-level, to that of the Pic du Bergons, 2113 meters. There were only eight observations in all, made at noon, one in July, four in September, one in October, and two in November. The constant deduced from these observations, after being reduced to sea-level, was 18336*. With the knowledge we now have of the large annual and diurnal inequalities in barometric determinations of altitudes made at different seasons of the year and hours of the day, together with all the other irregularities and uncertainties of results from only one or a few observations, a constant obtained from only eight pairs of observations, made mostly in the summer season, and all at the same hour of the day, cannot be accepted as being reliable. Yet this constant has been almost exclusively used even up to the present time.

13. The formula (25) requires the height of the barometer at both stations to be either that of the temperature of 0° C., or some other temperature, as that of the lower station, and also that it should be measured with a scale reduced to the standard temperature of the scale used in the construction of the barometer. It is usual to apply such reductions at once to the observations, but where unreduced observations are used it is necessary to introduce another correction into the formula, which will have the same effect upon the result as the reduction of the observations.

The general formula for this reduction, first given by Schumacher, is

$$-\frac{m(\tau-T)-l(\tau-\vartheta)}{1+m(t-T)}B$$

in which

$\tau$ = the temperature of the attached thermometer,
$T$ = the temperature to which the observed height is reduced,
$m$ = the coefficient of the cubic expansion of mercury,
$l$ = the coefficient of lineal expansion of brass,
$\vartheta$ = the normal temperature of the standard scale.

In this small reduction the denominator above can be taken as equal to unity without any sensible error. In the French barometer and scale we have, for reduction to the freezing point, $T=0$, and $\vartheta=0$, and hence the reduction becomes

$$-(m-l)\tau B$$

Hence, with the barometer unreduced, we shall have, using $B_1$ instead of $B$ in this case,

$$\log\frac{B''}{B}=\log\frac{B''_1(1-(m-l)\tau')}{B_1(1-m-l)\tau)}=\log\frac{B''_1}{B_1}+\log[1-(m-l)(\tau'-\tau)]$$

According to Regnault, the value of $m$ at 0° of temperature is .00017905, and at 30°, .00018051. The mean corresponding to an average temperature of 15° is .00017978. The coefficient of linear expansion of brass, according to Lavoisier and Laplace, is .00001878. Hence, we have in the expression above, where the barometer has a brass scale extending down to the base of the mercurial column, $(m-l)=.000161$. The preceding equation, therefore, becomes

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* Mémoires sur la Formule Barométrique de la Mécanique Céleste; par Ramond, 1811.

$$(26)\qquad \log\frac{B''}{B}=\log\frac{B''_1}{B}+\log[1-.000161(\tau'-\tau)]$$

For the English barometer, in which the standard temperature of the scale is 62° Fahr., the reduction to the freezing point becomes

$$-[m(\tau-32^\circ)-l(\tau-62^\circ)]B$$

in which $\tau$ must be expressed in degrees Fahrenheit, and the values of $m$ and $l$ changed to correspond by taking five-ninths of their values in the preceding case. Hence, it becomes

$$-[.00009988\tau-32^\circ-.00001043(\tau-62^\circ)]B=-.00008945(\tau-28^\circ.6)B$$

Proceeding as above, therefore, we get in this case

$$(27)\qquad \log\frac{B''}{B}=\log\frac{B''_1}{B_1}+\log[1-.0000895(\tau'-\tau)]$$

14. In the expression of H (25) it is necessary to know the value of $e$ for both the lower and upper stations, and this depends by (4) upon that of $b$. According to Regnault, we have

$$(28)\qquad b=b_1-\frac{0.480(t-t_1)}{610-t_1}B$$

in which $t_1$ is the temperature indicated by the wet-bulb thermometer, and $b_1$ is the vapor tension of saturated air at the temperature $t_1$.

When the wet bulb becomes coated with ice the formula becomes

$$(29)\qquad b=b_1-\frac{0.480\ (t-t_1)}{689-t_1}B$$

From comparisons recently made by Dr. Carl Koppe, in Zürich, and also by Herr Billwiller, between hair-hygrometers and the psychrometer, at temperatures below the freezing point, it is evident that this part of the formula is very erroneous. (Zeit. der Oest. Gesell. für Met., B. 13, § 49.)

Equation (4), therefore, becomes, when the wet bulb is free from ice,

$$e=\frac{b_1}{B}-\frac{0.480\ (t-t_1)}{689-t_1}=\frac{b_1}{B}-.0008(t-t_1)$$

the last form of the expression being correct for $t_1=10^\circ$ is sufficiently correct for all values of $t_1$. When the wet bulb is covered with ice the numerical coefficient of $(t-t_1)$ is .0007. We, therefore, have in (25) the factor

$$(30)\qquad 1+.189\ (e'+e)=\left(1+.189\frac{b'_1}{B'}\right)\left(1+.189\frac{b_1}{B'}\right)[1-.000151(t'-t'_1)]\ [1-.000151(t-t_1)]$$

When the wet bulb is covered with ice the numerical coefficient in the last two factors becomes .000136.

The formula of (28) is imperfect, and entirely fails for very low percentages of humidity. Where $t-t_1$ is very large the last term becomes the greater, and then the expression of $b$ becomes negative, that is, we have a negative vapor tension, which, of course, is an absurdity. If the formula entirely fails for very low percentages of humidity, it must begin to be inaccurate where the percentage of humidity is not very small. As the numerical coefficient, however, in the formula was determined empirically so as to satisfy observation and experiment for ordinary ranges of humidity, the formula for these is sufficiently accurate.

Instead of a formula for giving directly the vapor tension, Mr. Glaisher gives a formula of the form

$$(31)\qquad t_2=t-F\ (t-t_1)$$

for determining the temperature of the dew-point $t_2$, and then with this he gets from a table giving the tension of vapor in saturated air for the different temperatures the value of $b$. In the expression of $t_2$ above, the factor F is not a constant for all temperatures, but a function of $t$, which is determined from observation. These factors, determined from a great number of observations, are given in the following table of

*Glaisher's factors.**

| *t* | F. | *t* | F. | *t* | F. | *t* | F. | *t* | F. | *t* | F. | *t* | F. | *t* | F. | *t* | F. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 8.78 | 20 | 8.14 | 30 | 4.15 | 40 | 2.29 | 50 | 2.06 | 60 | 1.88 | 70 | 1.77 | 80 | 1.68 | 90 | 1.63 |
| 11 | 8.78 | 21 | 7.88 | 31 | 3.70 | 41 | 2.26 | 51 | 2.04 | 61 | 1.87 | 71 | 1.76 | 81 | 1.68 | 91 | 1.62 |
| 12 | 8.78 | 22 | 7.60 | 32 | 3.32 | 42 | 2.23 | 52 | 2.02 | 62 | 1.86 | 72 | 1.75 | 82 | 1.67 | 92 | 1.62 |
| 13 | 8.77 | 23 | 7.28 | 33 | 3.01 | 43 | 2.20 | 53 | 2.00 | 63 | 1.85 | 73 | 1.74 | 83 | 1.67 | 93 | 1.61 |
| 14 | 8.76 | 24 | 6.92 | 34 | 2.77 | 44 | 2.18 | 54 | 1.98 | 64 | 1.83 | 74 | 1.73 | 84 | 1.66 | 94 | 1.60 |
| 15 | 8.75 | 25 | 6.53 | 35 | 2.60 | 45 | 2.16 | 55 | 1.96 | 65 | 1.82 | 75 | 1.72 | 85 | 1.65 | 95 | 1.60 |
| 16 | 8.70 | 26 | 6.08 | 36 | 2.50 | 46 | 2.14 | 56 | 1.94 | 66 | 1.81 | 76 | 1.71 | 86 | 1.65 | 96 | 1.59 |
| 17 | 8.62 | 27 | 5.61 | 37 | 2.42 | 47 | 2.12 | 57 | 1.92 | 67 | 1.80 | 77 | 1.70 | 87 | 1.64 | 97 | 1.59 |
| 18 | 8.50 | 28 | 5.12 | 38 | 2.36 | 48 | 2.10 | 58 | 1.90 | 68 | 1.79 | 78 | 1.69 | 88 | 1.64 | 98 | 1.58 |
| 19 | 8.34 | 29 | 4.63 | 39 | 2.32 | 49 | 2.08 | 59 | 1.89 | 69 | 1.78 | 79 | 1.69 | 89 | 1.63 | 99 | 1.58 |

With regard to these factors Mr. Glaisher says: "The numbers in the table have been found from the combination of many thousands of simultaneous observations of the dry and wet bulb thermometers with Daniell's hygrometer, taken at the Royal Observatory, Greenwich, from the year 1844 to 1854, with observations taken at high temperatures in India, and others at low and medium temperatures at Toronto. The results at the same temperature were found to be alike at these different places; and, therefore, the factors may be considered as of general application."

These factors were also verified for high altitudes by observations made during his balloon ascents. "The result of all the simultaneous determinations of the temperature of the dew-point by Daniell's hygrometer and the dry and wet bulb thermometers are as follows: The temperature of the dew-point, as found by the use of the dry and wet bulb thermometers:

"Up to 1,000 feet high, was 0°.15 lower than by Daniell's hygrometer, from twenty eight experiments.

"From 1,000 to 2,000 feet high, was 0°.10 lower than by Daniell's hygrometer, from forty experiments.

"From 2,000 to 3,000 feet high, was 0°.05 lower than by Daniell's hygrometer, from fifty-nine experiments.

"From 3,000 to 4,000 feet high, was the same as by Daniell's hygrometer, from sixty-six experiments.

"From 4,000 to 5,000 feet high, was 0°.05 lower than by Daniell's hygrometer, from forty experiments.

"From 5,000 to 6,000 feet high, was 0°.7 lower than by Daniell's hygrometer, from thirty-four experiments.

"From 6,000 to 7,000 feet high, was 0°.2 lower than by Daniell's hygrometer, from thirty-four experiments.

"From 7,000 to 8,000 feet high, was the same as by Daniell's hygrometer, from eight experiments.

"From 8,000 to 9,000 feet high, was 1°.5 higher than by Daniell's hygrometer, from two experiments.

"From 9,000 to 10,000 feet high, was 1°.2 higher than by Daniell's hygrometer, from two experiments.

"From 10,000 to 11,000 feet high, was 0°.3 higher than by Daniell's hygrometer, from one experiment.

"From 12,000 to 13,000 feet high, was 0°.3 higher than by Daniell's hygrometer, from five experiments.

"From 13,000 to 14,000 feet high, was 0°.8 lower than by Daniell's hygrometer, from seven experiments.

"From 14,000 to 15,000 feet high, was 1°.0 lower than by Daniell's hygrometer, from two experiments.

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* Hygrometric Tables, by James Glaisher, F. R. S., &c, fifth edition: London, 1869.

"The number of experiments made up to the height of 7,000 feet, varying from twenty-eight to sixty-six in each step of 1,000 feet, are sufficient to enable us to speak with confidence; the results are that the temperatures of the dew-point as found by the use of these tables are worthy of full confidence up to this point. At heights exceeding 7,000 feet my experiments do not yield a sufficient number of simultaneous readings to give satisfactory results, and before we can speak with certainty at these high elevations more experiments must be made."*

But the tensions of aqueous vapor obtained by Glaisher's method by means of the factors in the preceding table, based upon so many observations made in different parts of the earth and at nearly all accessible latitudes, differ very much in some cases from those given by Regnault's formula in (28). Both Glaisher's formula and Regnault's have been reduced to tables; the former by Glaisher himself, the latter by Guyot and others. From a comparison of these tables the discrepancies shown in Table XII are obtained. In Guyot's tables the computations by the formula extend only to the point where the tensions vanish and change signs, and it is seen that at this point the tension given by Glaisher's table is still considerable.

It is a question with meteorologists why these tables, having the high authorities of Regnault and Glashier, should differ so much, and which should have the preference; but a little insight into the history of Regnault's formula clears up the matter. What is called Regnault's formula was, originally, a formula obtained by M. August from purely theoretical considerations. The constants in this formula were somewhat changed by Regnault after the data upon which they depend became better known, and the results then given by the formula were compared with those obtained by him from experiment and observation. The result of the comparisons was that it was necessary to change the theoretical constant 0.429 to 0.480, as given in (28), in order to ive the best agreement between the results of the formula and those of experiment and observation.

With regard to the theory upon which the formula is based, Regnault says: "I do not think that the fundamental hypothesis adopted by M. August can be admitted as a basis of the calculation of the psychrometer; namely, that all the air which supplies heat to the moist thermometer falls to the temperature $t'$ indicated by the latter, and is completely saturated with humidity. It seems to me probable that the portion of the air which cools does not fall to $t'$, and that it is not saturated with humidity. The relation of the quantity of heat which the air takes from the bulb by evaporation of the water to the quantity of heat which it loses in cooling is probably greater in proportion as that air is more dry, because in this state it is much more susceptible of humidity than when it approaches its state of saturation."†

With regard to his comparisons, he says: "The coefficient 0.480 gives an almost perfect coincidence between the calculated results and those found by direct observation in the fractions of saturation which exceed 0.40; but it produces a difference greater than the coefficient 0.429, and, in an inverse direction, for weaker fractions of saturation." He hence infers that the coefficient of the formula (28) depends on $t-t_1$, and that this "results from the fact that the air carries off proportionally more vapor when it is very dry than when it approaches saturation."

Regnault, then, not only does not consider the theory upon which the formula is based reliable, but says, also, that the formula with the empirical constant 0.480 does not give results in accordance with observation in fractions of saturation below 0.40. By referring to Table —— it is seen that for ordinary ranges of temperature and humidity the two tables agree as well as could be expected, and it is only in the case of extreme temperatures and low percentages of relative humidity that the differences become large. This is exactly what we should expect from what Regnault says of the empirical constant, for he says it fails for low percentages of humidity, and for very low percentages we know it entirely fails, since it gives negative tensions. Regnault had less than 100 observations, in all, for comparison; while, as we have seen, Glaisher had many thousands, so that the results obtained from Glaisher's factors and tables are undoubtedly more reliable, at least for small altitudes above sea-level, than those obtained from Guyot's tables computed from the formula of (28). But there is really little difference, so far as we can now see, between Regnault and Glaisher, since the results given by Guyot's tables differ from those of Glaisher's but little, except for low percentages of humidity, for which, Regnault says, the formula from which Guyot's tables have been computed is not accurate. That Regnault not only regarded the formula as being imperfect, but also that a new formula was desirable, is evidenced from a closing remark. He says: "I shall abstain for the present from establishing a new formula of the psychrometer; I do not consider the elements at my disposal as sufficient." It does not appear that he ever undertook it, but it has been done by Glaisher with an abundance of material on hand; with what success must be judged from comparisons of the results with observation. The trouble, then, with regard to the differences between the tables, is not that there is a difference between two great authorities, but that a formula called Regnault's formula, but confessedly imperfect, has been reduced to tables, which carry with them the authority of Regnault while they really have no such authority.

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* Glaisher's Hygrometrical Tables.

† Regnault's Hygrometrical Researches; Taylor's Scientific Memoirs, vol. iv, p. 652.

15. By a reference to the formulæ (28) and (31) it is seen that the former is a function of the barometric pressure, and that the tension $b$ should increase with altitude or diminution of pressure, all the other data remaining the same; while according to the latter the value of $t_2$, and consequently of $b$, is the same for all altitudes. Hence, if the two formulæ gave accordant results at the earth's surface generally, they would differ for high altitudes, especially for low percentages of humidity, in which the last term of (28) becomes large. Unless the theory of M. August, upon which the formula of (28) is based, is entirely erroneous, and the approximate accuracy of the theoretical coefficient 0.429 is merely accidental, I cannot see how the tension of vapor for the same temperatures of dry and wet bulb can be the same at all altitudes. As the pressure is diminished the evaporation, all other circumstances being the same, must be accelerated, and the difference between the dry and wet bulb temperatures diminished, and hence the formula (31) must give too small a vapor tension. Yet the comparisons of the results given by Glaisher's factors with observations at high altitudes, we have seen, seem to be satisfactory, and there are no indications that the tensions for the same temperatures of dry and wet bulb increase with altitude as they must by the formula of (28). Regnault had no observations of much weight in testing the formula in this respect, and remarks that it will be desirable to make experiments in very elevated localities to ascertain whether the second term in (28) corrects properly the formula for the variations of B. If a series of such experiments were made on Pike's Peak, or at some other very elevated station, they would be of great value in settling this question.

It is seen from Table XII that, for low altitudes above sea-level and small fractions of saturation, the vapor tensions given by (28) are smaller than those given by Glaisher's factors and tables; but these tensions are the same by the latter for all altitudes, while by the former they must increase as B diminishes, that is, as the altitude increases. For altitudes from one to two miles the differences between the results of formula (28) and those of Glaisher's factors are generally small and of little consequence in barometric hypsometry. For differences of altitude, therefore, of about three miles, where the lower station is near sea-level, if formula (28) is used for obtaining the vapor tensions of the air, the results in determining differences of altitude by (25) will differ but little from those obtained with Glaisher's vapor tensions, since at the lower station the value of $e'$ with the former is smaller and at the upper station the value of $e$ is larger than they would be with the use of Glashier's vapor tensions, and consequently the value of $(e'+e)$ in (25) is very nearly the same with both. For small differences of altitude the uncertainty in the hygrometrical formula is of little consequence. The formula of (28) will, therefore, be used in obtaining $b$, and with it the value of $e$ in (4), in applications of the formula (22) or (25), so that if Glaisher's factors are correct for high altitudes, the results obtained with formula (28), instead of Glaisher's factors, must also be nearly correct, even in cases in which the differences of the vapor tensions obtained by either method are of any consequence, namely, where there are large differences of altitude and low percentages of humidity.

16. It must be borne in mind that formula (25) is correct only in the case in which the decrease of temperature and of the value of $e$ is very nearly as the increase of altitude, and that, even with the correction C in (22) it is strictly applicable only to the case in which the decrease of these quantities with increase of altitude can be expressed by the first two terms of the expressions of (16), and in which the second term is small in comparison with the first. In the annual and diurnal averages of one or more years this is, perhaps, always the case, and it may often be so in

individual cases of mean temperatures, where the observations are made in the spring or fall and at the hours of the mean temperature of the day. If, in such a case, A*c* (Fig. 1) represent the surface temperature $t''$ at D under the upper station, the mountain being supposed to be removed, and this temperature to be determined from observations at A reduced to the point D by means of a chart of well-determined temperature gradients, or by means of simultaneous observations at several stations around the mountain; and if, likewise, C*c* represent the observed temperature at the upper station at B, then the intervening temperatures on the vertical between D and B will be represented very nearly by the horizontal co-ordinates of the straight line *ac* referred to the line AC, making these temperatures decrease in proportion to the increase of the altitude. In this case $\frac{1}{2}(t''+t)$ represents the average temperature of the vertical line DB, and the formula (25) is very nearly correct, since $c'$ vanishes and the correction C (23) becomes very small.

In the summer season, especially during the warmest part of the day, the temperatures of all the strata are very much increased, but the surface temperature at the lower station, especially if situated on a dry plane and at a considerable distance from the sea or other large body of water, or in some mountain valley, becomes very much greater in proportion than that of the air at only a small elevation above the surface, and the temperature of the upper station at B may also be considerably higher than that of the air generally around about B at the same altitude, but at some distance from the heated surface of the mountain, or than it would be at B if the mountain with its superheated surface were removed, and this is especially the case for both stations in clear weather. In this case if A*b* (Fig. 1) represent the temperature $t''$ at the level of the lower station at D, and CD represent the temperature observed at B, and C*e* that which would exist at B if the mountain were away, then the intervening temperatures of the vertical DB will not be represented by the co-ordinates of the straight line *bd*, but by those of some curved line *be*, which makes the temperatures decrease with increase of altitude in a much greater ratio near the surface than at altitudes at some elevation above the surface. The value of $\frac{1}{2}(t''+t)$, therefore, is in this case greater than the average of the temperatures which would exist between D and B if the mountain were away in the ratio of the area AC*db* to that of AC*eb*, so that with this value of $\frac{1}{2}(t''+t)$, instead of the true average of the temperatures, we get from (25) a value of H which, in the summer season, is generally too great. Even the formula with the correction C (23) is not applicable in this case, since, on account of the rapid decrease of temperature with increase of altitude near the surface, the temperature cannot be represented by the form of (16), at least unless the second term becomes too large in comparison with the first for the formula to be applicable, and even if it were, we would have no means of determining the constants $c$ and $c'$ in that expression.

But if the lower station or stations, from which the temperature $t''$ is determined, are situated near the sea, or large lake, where the annual range of temperatures may not be so great as that of the temperatures of the air above, then the value of $t''$ obtained from the observations at those stations may be such as to make $\frac{1}{2}(t''+t)$ less than the true average, and then the value of H from formula (25) may be too small. This would especially be the case if the value of $t$, observed at the upper station B, were, for some reasons, also less than the temperatures generally in the vicinity at that altitude. This may be the case often where the station B is located high up on the top of a mountain peak, for, as in warm weather there are always ascending currents up the mountain sides, the rate of decrease of temperature with increase of altitude approximates to that of rapidly-ascending currents, which in the case of dry air is about one degree for each 100 meters of ascent. But this is a much more rapid decrease of temperature than that which exists in the air generally, and hence the air of these currents when it arrives at the top of the peak may be colder than that of the air generally in the vicinity at that altitude, and than the air at B would be if the mountain were away and there were no ascending currents.

In the winter season, and especially during the coldest part of the day, we have just the reverse of what takes place in the summer season. Then the surface temperatures at both A and B (Fig. 1), on account of the greater radiation from the surface than from the air, are much more diminished than those of the air generally at some height above the surface, so that if in this case A*b* represent the temperature $t''$, and C*d'* that of $t$ observed at B, and C*e'* that of the temperature at that elevation unaffected by the cooler mountain surface, then the temperatures of the vertical DB are not represented by the co-ordinates of the straight line *b'd'*, but by those of the curved line

$b'e'$, and the value of $\frac{1}{2}(t''+t)$ is less than the mean temperature of the air column DB would be if the mountain were away, in the ratio of the area $ACd'b'$ to that of $ACe'b'$, and the formula (25) therefore gives generally too small a value for H in the winter season, especially for the coldest part of the day.

But if the lower station, or stations, from which $t''$ is determined, are situated near large bodies of water, the temperature of which may be considerably higher than that of the air above them, then the value of $\frac{1}{2}(t''+t)$ in the formula, as determined from the observations, may be greater than the mean temperature required, as in the summer it may sometimes be too small, and then the formula may give values of H too great instead of too small in the winter season and coldest part of the day.

17. The correction in the formula for the effect of the aqueous vapor of the air is so small that the mean of the two extremes $\frac{1}{2}(e'+e)$ can always be used without any sensible error for the average value of $e$, and the value of $e'$ may be that observed at the lower station without any reduction to the point D (Fig. 1), as in the case of the temperature, when the distance between the stations is great.

Where hygrometric observations are made at the lower station only, the most probable value of the vapor tension $b$ at the level of the upper station may be obtained from $b'$, its value at the lower station, by means of the formula

$$\log b = \log b' - \frac{H^{m}}{6517} = \log b' - \frac{H^{ft}}{21380} \tag{32}$$

The first expression of the value of $\log b$ must be used for French measures, and the latter for English. These are simply modified forms of those deduced by Dr. Hann,* for the average state of the atmosphere, based upon hygrometric observations made by different observers at various places on the Himalayas, Mount Arrarat, Teneriffe, and also in the balloon ascensions of Welsh and Glaisher. Even where hygrometric observations are made at the upper station this formula would no doubt give a better value for the formula than the observed value at the upper station, especially in the summer season when there are ascending currents and the air at the mountain top becomes saturated from the ascending moist and gradually cooling current of the mountain side, while the air at the level of the upper station generally is comparatively dry.

Where no hygrometric observations are made at either station it is usual to use Laplace's modified temperature coefficient in the formula as a partial, though very imperfect, correction for the effect of the aqueous vapor. For low temperatures this correction is known to be very erroneous, and for temperatures below the freezing point the correction even has the wrong sign and makes the final result more erroneous. In this case also it is better to use a vapor tension for each degree of temperature, which is an average somewhat of tensions observed at that temperature at various places and different seasons of the year. This may be done by substituting in (3) for $f(e)$, its value given by the expression in § 8, Part I, which has been obtained by Dr. Hann from observations made at various times and places, and may be regarded as an empirical approximate expression for the average state of the atmosphere. With this expression of $f(e)$ we get instead of $.189(e'+e)$ in (25) the expression $0.00154 + .000341t$. This makes the correction for the hygrometric state of the atmosphere a function of the temperature, as the correction introduced by Laplace by means of his modified temperature coefficient, but the latter makes this correction vanish and change signs at 0° $c$, while in the former this takes place at $-4^{\circ}.5$. Both are therefore imperfect for low temperatures, since the vapor tension most probably never vanishes at any temperature, or at least it cannot become negative. The expression above can be used without any sensible error where a series of observations, made at different times, is used, as those of monthly or yearly averages; but of course, in special cases, where only one or a very few sets of observations are used, it will generally be less accurate.

18. By putting $\Delta H$, $\Delta B$, and $\frac{1}{2}\Delta(t''+t)$ for small finite variations of the altitude, barometric pressure, and of mean temperature of the two stations, we get from the differentiation of (25), neglecting insensible quantities and using the approximate mean correction given above for the effect of aqueous vapor,

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*Zeitschrift der Oesterr. Gesell. für Meteorologie, ix Band, Seite 198.

$$(33)\quad \varDelta\mathrm{H}=18447\mathrm{M}\left(\frac{\varDelta\mathrm{B}''}{\mathrm{B}''}-\frac{\varDelta\mathrm{B}}{\mathrm{B}}\right)[1+.00183(t''+t)][1+.00154+.000170(t'+t)]+.00183\mathrm{H}\varDelta(t''+t)$$

$$= 8024\left(\frac{\varDelta\mathrm{B}''}{\mathrm{B}''}-\frac{\varDelta\mathrm{B}}{\mathrm{B}}\right)[1+.002(t''+t)]+.00183\mathrm{H}\varDelta(t''+t)$$

By means of this expression, the effect upon H, in formula (25), resulting from small errors in barometric pressure and in temperature, may be conveniently computed.

If in (25) we put $\delta$H for the change of altitude corresponding to a very small change of pressure $\delta$B in ascending, letting B′ and B represent the barometric pressures at the base and top of this short column, in which $t'$ may be put equal to $t$, we shall have, for the mean hygrometric state of the atmosphere and the parallel of 45°,

$$(34)\qquad \delta\mathrm{H}=-8024\frac{\delta\mathrm{B}}{\mathrm{B}}(1+.004t)$$

Putting $\delta\mathrm{B}=1^{\mathrm{mm}}$, we get

$$(35)\qquad \delta\mathrm{H}=-\frac{8024}{\mathrm{B}}(1+.004t)$$

for computing the value of $\delta$H for a change of $1^{\mathrm{mm}}$ in the value of the barometric pressure at any given temperature $t$. In these expressions the values of B and $t$, strictly, should be the means of the small column $\delta$H, and B must be expressed in millimeters.

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## CHAPTER II.

## PRACTICAL APPLICATIONS OF THE THEORY.

19. By means of the formulæ in the preceding chapter, with the necessary barometric, temperature and hygrometric observations, the difference of altitude between any two stations can be computed, with results more or less accurate, according to the accuracy of the observations and the conformity of the temperature and hygrometric state of the atmosphere with that assumed in the formulæ. Small, unavoidable errors in observations may affect these results considerably, but the greatest errors arise, as explained in § 16, from assuming that the average temperature and hygrometric state of the air column is the mean of the observations at the lower and upper stations. These errors affect the results, not only in the case of one or a few sets of observations, made at any time of the day or season of the year, but likewise in the case of monthly averages. With a great number of observations, however, made at different seasons of the year and hours of the day, and especially if these observations are made regularly throughout the year, and at such hours of the day as give the mean temperature nearly of the day, these errors are in a great measure eliminated from the result. But even in this case there is considerable uncertainty where we do not have the means of determining the permanent barometric gradient of the place, if the two stations are a considerable distance apart.

The practical application of the preceding formulæ can be very much facilitated by means of computed tables, adapted to the several variables in the formulæ used as arguments. Such tables have been computed with the improved and most recent constants given in the preceding formulæ, and much study has been given to this part of the subject, in order to have these tables as concise and convenient as possible. Such tables are much needed in this country, since the tables in use here mostly are based upon the old constant, determined by Ramond nearly eighty years ago, which is now known to be erroneous. This constant has been used in seven of the eight different formulæ and sets of tables given in the Smithsonian Miscellaneous Collections, the eighth being Bessel's formula with the constants corrected by Plantamour in accordance with Regnault's determination of the densities of mercury and air, but with corresponding tables adapted only to French measures. Besides, neither the formulæ nor the tables are in the most convenient form for practicable application. Williamson has reduced these formulæ to tables in English measures, adapted to computation without logarithms, but such tables require great expansion and are inconvenient, both on account of their great bulk and because they must necessarily be tables with two arguments; for every computer knows how inconvenient it is to obtain numbers accurately by interpolation from a table with two arguments.

The tables here given are arranged more after the concise and admirable forms given by Rühlman, but are given in English instead of French measures. They are, however, so arranged that they can be used with almost the same convenience in the latter as in the former measures. With one exception they are all tables with a single argument, and the quantities to be taken from the table with two arguments are generally so small that they can be obtained with sufficient accuracy with very little trouble. These tables are adapted to computations with the use of logarithms, which is most convenient where a table of logarithms is at hand, but it may sometimes be desirable to have tables by which the computations can be made without the use of logarithms. For this purpose a mode of computation without logarithms has been devised in which the same tables, with one exception, can be used, and therefore requiring only one additional table, instead of a complete and separate set of tables.

20. The principal constant in (25), reduced to feet, is 60521.5, and the term .00183 $(t''+t)$, for degrees Fahrenheit becomes .001017 $(t''+t-64°)$. With these changes the formula (25), by means of (30), can be put into the following form adapted to English measures and computation by logarithms:

| | |
|---|---|
| $\log H = \log(\log B'' - \log B)$ | |
| $+\log 60521.5\,[1+.001017\,(t''+t-64°)]$ | Table I, arg. $(t''+t)$ |
| $+\log\left(1+.189\,\dfrac{b'_1}{B'}\right)$ | Table II, arg. $b'_1$ and B′ |
| $+\log\left(1+.189\,\dfrac{b_1}{B}\right)$ | Table II, arg. $b_1$ and B |
| $+\log\,[1-.000084\,(t'-t'_1)]$ | Table III, arg. $t'-t'_1$ |
| $+\log\,[1-.000084\,(t-t_1)]$ | Table III, arg. $(t-t_1)$ |
| $+\log\left(1+\dfrac{2h'}{r}\right)$ | Table V, arg. $h'$ |
| $+\log\left(1+\dfrac{H}{r}\right)$ | Table VI, arg. log H |
| $+\log\,(1+.002606\cos 2\lambda)$ | Table VII, arg. $\lambda$ |

If the barometer has not been reduced to the temperature of 32° Fahr., the second member of (27) must be used instead of $\log B''-\log B$, that is, we must deduct from this the value of log $[1-.0000895\;(\tau'-\tau)]$ when $\tau$ is expressed in degrees of Fahrenheit. This logarithm is contained in Table VIII.

The following are the definitions of the quantities entering into the terms and arguments, given here again by way of recapitulation and for the sake of convenience of reference:

$H$=the difference of altitude of the two stations,

$B$=the barometric pressure at the upper station,

$B'$=the barometric pressure at the lower station unreduced for barometric gradient.

$B''=B'$ reduced to the latitude and longitude of the upper station by applying a correction for the barometric gradient,

$t$=the temperature of the air at the upper station,

$t'$=the same at the lower station,

$t''=t'$ reduced to the latitude and longitude of the upper station by applying a correction for the temperature gradient,

$b_1$=the vapor tension of saturation at the temperature of the wet bulb at the upper station,

$b_1'$=the same for the lower station,

$t_1$=the temperature of the wet bulb at the upper station,

$t_1'$=the same for the lower station,

$h'$=the altitude of the lower station above sea-level,

$\lambda$=the latitude of the upper station,

$\tau$=the temperature of attached thermometer at the upper station,

$\tau'$=the same for the lower station.

The logarithm of the first term in the preceding formula can be obtained from any table of logarithms of five or six places, and that of each of the other terms can be very conveniently obtained from the tables designated with the arguments corresponding to each. Table II can be used where $b_1$ and B are given in millimeters by multiplying each by .04 or any other number which will bring the products within the limits of the range of the arguments given in the table. Table III needs only to be entered once if the sum of the arguments of the terms is used, that is, $(t'-t'_1)+(t-t_1)$.

It is usual to reduce barometric readings to the temperature of freezing, but where observations are made solely for the purpose of determining differences of altitude it is best to not correct them for temperature, if the barometer, as usual, has a brass scale extending down to the cistern; for in such case the effect of the correction is more conveniently applied to the result by means of Table VIII, which is very small, and the argument readily obtained. In reducing each of the readings to the temperature of freezing, a comparatively large table has to be entered twice and two corections have to be applied.

Where the vapor tensions are given instead of the temperature of the wet bulb, $t_1$, of the psychrometer, as frequently happens, Table III must be omitted and Table II used with the arguments $b'$ and $b$ instead of $b'_1$ and $b_1$. In this case $b'$ and $b$ are obtained from Table IX (Table X for French measures) with $t'$ and $t$ as arguments. But where hygrometric observations are made especially for determining differences of altitude, it is most convenient to use Table III and Table II with $b'_1$ and $b_1$ as arguments, since this saves the labor of obtaining from formula (28) the values of $b'$ and $b$, for this, even where the last term in the formula is reduced to a table, requires considerable time, while the use of Table III is very convenient, the table being very small, and having only one argument, which is very readily obtained.

It often happens that no hygrometric observations are made at either station. When this is the case Table IV must be used instead of Tables II and III. This table is computed from the expression of $f(e)$, given in §17, reduced to English measures for the higher temperatures, but for the lower temperatures the numbers are increased a little to remedy the defect of this expression for low temperatures and to make the numbers for these temperatures positive. In all cases in which yearly averages are used this table can be used without any sensible error, and even with monthly averages, or averages of any series of observations extending over a considerable period of time, the error is very small.

21. The preceding expression of log H can be put into the following form:

$$\log \mathrm{H}=\log 60521.5\left(\log \frac{30}{\mathrm{B}}-\frac{30}{\mathrm{B}''}\right)(1+.001017\times 36^\circ)+\Sigma_s \log (1+\mathrm{N}_s)$$

in which

$$\mathrm{N}_1=.001017\ (t''+t-100^\circ)$$

$$\mathrm{N}_2=.189\frac{b'_1}{\mathrm{B}'}$$

$$\mathrm{N}_3=.189\frac{b_1}{\mathrm{B}}$$

&c., &c.

This arrangement makes $\mathrm{N}_1$ vanish at the mean temperature of 50° Fahr., and hence makes it small for either extreme; and as all the other values of $\mathrm{N}_s$ are generally small, the value of the last term in the expression above is small. We can therefore put

$$\mathrm{H}=(\mathrm{A}-\mathrm{A}')\,(1+c)$$

in which

$$\mathrm{A}=60521.5 \log \frac{30}{\mathrm{B}}\,(1+.001017\times 36^\circ)$$

$$\mathrm{A}'=60521.5 \log \frac{30}{\mathrm{B}''}\,(1+.001017\times 36^\circ)$$

$$c=\frac{\Sigma_s \log (1+\mathrm{N}_s)}{\mathrm{M}\,(1-\frac{1}{2}c)}=2.3\Sigma_s\frac{\log (1+\mathrm{N}_s}{1-1.15\ \Sigma_s \log (1+\mathrm{N}_s)}, \text{ very nearly.}$$

The values of A and A′ are taken from table XI with the arguments B and B″. The value of log $(1+\mathrm{N}_1)$ is obtained from Table I, with the argument $(t''+t)$, by subtracting the logarithm opposite 100°, namely, 4.79753, and so it is negative when $t''+t$ is less than 100°. The other logarithms of $(1+N_s)$ are obtained from Tables II to VII, inclusive, as in the computation by the formula with logarithms. As the value of $c$ is always small, the only multiplication required is readily made, and the preceding formula, therefore, becomes very convenient for the computation of differences of altitude without the use of logarithms. The denominator in the expression of $c$ generally differs so little from unity that it may be neglected, and then the expression of $c$ becomes so simple that the value of $c$ can be readily obtained.

22. As a first example of the application of the formula and tables, let us assume the following data, in which B′ and B are supposed to be reduced to the temperature of 32° Fahr., and in which there is no sensible effect from a gradient, so that B′ can be used instead of B″:

| *Inches.* | ° | ° | |
|---|---|---|---|
| $B'=28.075$ | $t'=57.3$ | $t'_1=48.2$ | $h=2000$ feet |
| $B\ =22.476$ | $t\ =38.5$ | $t_1\ =32.4$ | $\lambda=38°$ |

With $t'$ and $t$ as arguments, Table IX gives $b'_1=0.470$ and $b_1=0.233$. With these data the computation is as follows:

| With logarithms. | | Without logarithms. | | |
|---|---|---|---|---|
| $\log B'=1.44832$ | | Table XI, arg. B | | $A\ =7867$ |
| $\log B\ =1.35172$ | | Table XI, arg. B′ | | $A'=1807$ |
| Diff. $=0.09660$ log diff. | 0.98498 | | | $A-A'=6060$ |
| Table I, with arg. $t'+t=95°.8$, | 4.79573 | Table I−4.79753, | −.00180 | |
| Table II, with arg. B′ and $b'_1$ above, | 138 | Table II, | 138 | |
| Table II, with arg. B and $b_1$ above, | 85 | Table II, | 85 | |
| Table III, with arg. $t'-t'_1=9°.1$ | −33 | Table III, | — 33 | |
| Table III, with arg. $t-t_1=6°.1$ | —22 | Table III, | — 22 | |
| Table V, with arg. $h'$ | 8 | Table V, | 8 | |
| Table VI, with arg. $\log H=3.78$ | 12 | Table VI, | 12 | |
| Table VII, with arg. $\lambda$ | 28 | Table VII, | 28 | |
| $\log H=$ | 3.78287 | | | $.00036\times2.3\times6060=5.8$ |
| $H=6065.5$ feet | | | | $H=\ 6065.8$ |

If we suppose the temperatures of the attached thermometer to have been $\tau'=55°$ and $\tau=36°$, then the uncorrected values of B′ and B would have been 28.141, and 22.491, respectively, and we should have had

| | |
|---|---|
| $\log B'=$ | 1.44934 |
| $\log B\ =$ | 1.35200 |
| Diff. $=$ | 0.09734 |
| Table IX, with arg. $(\tau'-\tau)=19°$, | .00074 |
| Diff. $=$ | .09660 |

This is the same as the difference in the preceding computation obtained from the reduced values of B′ and B.

23. As a second example, we shall take the averages of the observations made at Geneva and St. Bernard, given in § 26. These give

| | ° | | |
|---|---|---|---|
| $B''=726.5$ | $t''=\ 10.6$ C | $R'=76$ | $\lambda\ =45°\ 12'$ |
| $B\ =564.1$ | $t\ =-1.3$ C | $R\ =78$ | $h'=408^{m}$ |

From Table X we get, with $t''$ and $t$ as arguments, $f'=8.98$ and $f=4.18$. Hence $b'=8.98\times.76=6.84$ and $b=4.18\times78=3.27$. With these data the computation is as follows:

| | | |
|---|---|---|
| $\log B''=2.86124$ | | |
| $\log B\ =2.75136$ | | |
| Diff. | 0.10988 | log diff. 9.04092 |
| Table I, with $\frac{9}{5}(t''+t)+64°=80°.7$ as an argument, | | 4.78923 |
| Table II, with $726\times.04=29.0$ and $6.84\times.04=27.4$ as arguments, | | 78 |
| Table II, with $564\times.04=22.6$ and $3.27\times.04=13.1$ as arguments, | | 48 |
| Table V, with $h'$ as an argument, | | 5 |
| Table VI, with 3.83 as an argument, | | 14 |
| Table VII, with $\lambda$ as an argument, | | — 3 |
| Log of factor reducing to meters | | 9.48401 |
| | | $\log H=3.31558$ |
| | | $H=2068.2^{m}$ |

If in this example we had used Table IV instead of Table II, we should have had the logarithm .00141 instead of .00078+.00048=.00126. This would have given $\log H=3.31543$ and $H=2067.4$ instead of 2068.2.

With the preceding values of $b'$ and H we get from (32)

$$\log b=0.835-\frac{2068}{6517}=0.518, \text{ and hence } b=3.30.$$

This agrees almost exactly with the value of $b$ above from observations.

24. As another example let us take the means of the observations made by Professor Whitney at Sacramento and Summit on the top of the Sierra Nevada, a case in which no hygrometric observations were made, and consequently a case in which Table IV must be used instead of Tables II and III. The annual means of these observations, given in § 25, are

| *Inches.* | ° | |
|---|---|---|
| $B'=30.014$ | $t'=59.9$ | $h'=31$ feet |
| $B\ =23.288$ | $t\ =42.1$ | $\lambda\ =39°\ 20'$ |

We have no means of determining in this case the effect of barometric and temperature gradients, and hence we can do no better than to use $B'$ and $t'$ instead of $B''$ and $t''$. The computation in this case is as follows:

With logarithms.

| | | |
|---|---|---|
| $\log B'=1.47732$ | | |
| $\log B\ =1.36713$ | | |
| Diff. | 0.11019 | log diff. 9.04215 |
| Table I, with arg. $t'+t=102°.0$, | | 4.79838 |
| Table IV, with arg. $t'+t=102°.0$, | | 223 |
| Table VI, with arg. $\log H=3°.84$, | | 15 |
| Table VIII, with arg. $\lambda$, | | 21 |
| | | $\log H=\ 3.84312$ |
| | | $H=6968.1$ feet |

Without logarithms.

| | | |
|---|---|---|
| Table XI, with arg. $B_1$ | | $A\ =6901.0$ |
| Table XI, with arg. $B'_1$ | | $A'=-12.7$ |
| | | $A-A'=6913.7$ |
| Table I—4.79753, | .00085 | |
| Table IV, | 223 | |
| Table VI, | 15 | |
| Table VII, | 21 | |
| | Sum .00344 | $\times6914\times2.3=54.7$ |
| | | $H=6968.4$ feet |

25. Having given several examples of the application of the formula and tables to annual averages, we shall now give the results obtained in the same manner from the monthly averages. When the differences of altitude have been obtained from actual leveling, the result obtained from the formula should be the same, and when the true difference of altitudes is not known, the formula should give the same difference of altitude from each of the monthly averages.

From the monthly averages of barometric and temperature observations made by Professor

Whitney at Sacramento and Summit, California, from October, 1870, to October, 1873, given in his Barometric Hypsometry (pp. 32–34), the following averages of the three years are obtained:

| Month. | Observations. | | | | Results. | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $B'$ | $B$ | $t'$ | $t$ | $H$ | $\Delta$ | $\Delta'$ | $t'-t$ | Rate of change of $t$— | |
| | | | | | | | | | per 100 feet. | per 100$^m$. |
| | *In.* | *In.* | ° | ° | *Feet.* | | | ° | °F. | °C. |
| January | 30. 151 | 23. 288 | 47. 1 | 29. 2 | 6900 | − 65 | − 46 | 17. 9 | 0. 26 | 0. 47 |
| February | 30. 079 | 23. 153 | 48. 8 | 27. 3 | 6989 | + 24 | − 16 | 21. 5 | 0. 31 | 0. 56 |
| March | 30. 117 | 23. 262 | 54. 8 | 31. 6 | 6975 | 10 | + 18 | 23. 2 | 0. 33 | 0. 61 |
| April | 30. 051 | 23. 216 | 59. 3 | 33. 8 | 7020 | 55 | 48 | 25. 5 | 0. 36 | 0. 67 |
| May | 29. 935 | 23. 233 | 65. 5 | 44. 6 | 7021 | 56 | 64 | 20. 9 | 0. 30 | 0. 55 |
| June | 29. 932 | 23. 333 | 70. 9 | 54. 9 | 7016 | 51 | 63 | 16. 0 | 0. 23 | 0. 42 |
| July | 29. 892 | 23. 372 | 73. 7 | 61. 0 | 6995 | 30 | 46 | 12. 7 | 0. 18 | 0. 33 |
| August | 29. 910 | 23. 356 | 71. 3 | 59. 1 | 7000 | + 35 | + 16 | 12. 2 | 0. 17 | 0. 32 |
| September | 29. 911 | 23. 338 | 67. 4 | 53. 6 | 6954 | − 11 | − 18 | 13. 8 | 0. 20 | 0. 36 |
| October | 29. 984 | 23. 350 | 60. 2 | 46. 3 | 6901 | 64 | 48 | 13. 9 | 0. 20 | 0. 36 |
| November | 30. 099 | 23. 307 | 50. 8 | 34. 3 | 6896 | 69 | 64 | 16. 5 | 0. 24 | 0. 43 |
| December | 30. 109 | 23. 253 | 48. 7 | 29. 1 | 6914 | − 51 | − 63 | 19. 6 | 0. 28 | 0. 51 |
| Year | 30. 014 | 23. 288 | 59. 9 | 42. 1 | 6965 | ........ | ........ | 17. 8 | 0. 255 | 0. 466 |

The approximate latitude of Sacramento is 38° 35′, and that of Summit 39° 20′. The altitude of Sacramento is only about 30 feet above sea-level. The distance of Summit from Sacramento in a straight line is 77 miles, in a direction a little north of east. The exact difference of altitude between the barometers of the two stations, as ascertained from the railroad levelings, is 6,989 feet.

By computing the values of H from each set of monthly averages, as in the example of § 25, we get the values above. It is seen from the column headed $\Delta$, which gives the excess of each monthly value of H above the yearly mean, that there is a large annual inequality in these values of H, the values being too great in summer and too small in winter. These arise in part from abnormal irregularities in the averages, but mostly from assuming that the value of $\frac{1}{2}(t'+t)$ in the formula expresses the true average temperature of the air column between the levels of the two stations, as has been already explained in § 16.

If we suppose the monthly values of H, as given by the formula, to be represented by

$$H=A+B\cos(it-\varepsilon)$$

in case all abnormal irregularities were eliminated, then the most probable values of the constants B and $\varepsilon$ in this expression, as given by (26), (30), and (31), Part I, are $B=65.9$ feet and $\varepsilon=147°.8$. With these constants this expression gives the most probable values of $\Delta$, denoted by $\Delta'$ above, and such as would be obtained from a series of observations continued through so long a period of time that all abnormal irregularities would be eliminated. It also makes the maximum and minimum of this annual inequality occur about the first of June and December respectively, and the vanishing nodes about the first of March and September. The maximum of the inequality, therefore, does not occur in the middle of summer in this case, and the result indicates that the value of $\frac{1}{2}(t'+t)$ differs most from the true average temperature of the air column between the levels of the two stations, about the first of June and December. This arises from the surface temperatures, especially in the valley of the Sacramento, being increased more rapidly from the sun's radiations during the spring than the air is at some distance above the surface, and from being decreased more rapidly during the fall by the radiation from the surface.

The average of the monthly values of H above, 6,965 feet, differs 3 feet from the value of H obtained from the yearly means of the observations. Since the expression of H (25) is not strictly a linear function of the observation, the principle of using averages of observations is not strictly correct, especially in the case of the yearly means, in which the range of the observed values is very great. In the case of the monthly averages this range is less, and hence the mean of all the monthly values of H must be regarded as being more nearly correct than the value of H from the yearly means of the observations.

The mean of the monthly values of H, 6,965 feet, is 24 feet less than the true value obtained by leveling. This is probably due to the effects of barometric and temperature gradients in the mean annual pressures and temperatures, which have been necessarily neglected in the computations, since there were no means of determining them, so that the values of B′ and $t'$ were used instead of B″ and $t''$, which the formula requires. That there is an increase of mean annual temperature in a direction from Sacramento to Summit would seem to be indicated by the simultaneous temperature observations made by Professor Whitney at Colfax, an intervening station between Sacramento and Summit. The mean of the three years at Sacramento, as seen above, is 59°.9, while at Colfax, which has an altitude 2,400 feet greater, the mean temperature for the same time is 60°.6, and hence greater. This reduced to the level of Sacramento with any ordinary rate of decrease of temperature with increase of altitude would give a great increase of mean temperature from Sacramento to Colfax, a distance of only 45 miles. Of course there cannot be any but a very small general gradient extending a considerable distance in that direction, and the above result shows the great uncertainty in temperature observations at the earth's surface, arising from great local variations, or from differences of positions of the thermometers with regard to elevations above the surface, and from other causes. Hence the observations of surface temperatures at the two stations, even in the case of annual means, cannot be relied upon to give the average temperature of the air column between the level of the two stations. The difference above of 24 feet between the true and computed difference of altitude corresponds to an error in the mean temperature of the air column of about 2°. But a considerable part of the error in the computed value of H may be due to a gradient of increasing mean barometric pressure in the direction of Summit from Sacramento. A gradient which would cause the barometric pressure at Summit to be only 0.02 inches higher than at Sacramento, up at the same level, would account for the difference of 24 feet. It is not improbable that there is a gradient of that magnitude due to local causes of no great extent, but that there is such a gradient extending to a considerable distance is not probable.

Where there is a barometric gradient in the mean annual pressure, there is also an annual inequality in this gradient, and hence a small part of the annual inequality in the value of H, as given by the formula, may be due to this cause, but it is mostly due, no doubt, to errors in the average temperature of the air column, obtained from the mean of the two stations.

With the values of $(t'-t)$ in the preceeding table of results we get the last two columns, showing the rate of decrease of temperature with increase of altitude. The annual inequality in the monthly rates is very large, this rate being nearly twice as large in April as in October. This arises from the more rapid increase of temperature in the Sacramento Valley in the spring, than at Summit, where the increase of temperature in the spring is retarded by the melting of the snow on the mountains. The annual mean of this rate of decrease of temperature is less than usual, but if it had been determined by comparing the observations of temperatures at Colfax, instead of Sacramento, with those at Summit, the rate of decrease would have been found to be nearly twice as great. This shows the uncertainty in the rates of decrease of temperature with increase of altitude as determined from surface observations on the slopes of mountain sides.

25. Taking the average of observations made by Professor Whitney at Sacramento and Summit for the hours of 7 a. m., 2 p. m., and 9 p. m., we get the following averages:

| Hour. | Observations. | | | | Results. | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | B′ | B | $t'$ | $t$ | H | Δ | $t'-t$ | Rate of decrease— per 100 ft. | Rate of decrease— per 100$^{m}$. |
| | *Inches.* | *Inches.* | ° | ° | | | ° | °F. | °C. |
| 7 a. m... | 30.033 | 23.291 | 52.4 | 38.2 | 6897 | − 69 | 14.2 | 0.20 | 0.37 |
| 2 p. m... | 30.002 | 23.281 | 69.0 | 49.4 | 7089 | +123 | 19.6 | 0.28 | 0.51 |
| 9 p. m... | 30.007 | 23.293 | 57.3 | 38.7 | 6911 | − 55 | 18.6 | 0.27 | 0.49 |

These observations show a large range in the diurnal inequality of temperature at both stations, while there is scarcely any corresponding change in the barometric pressures. Between

7 a. m. and 2 p. m. the means of the temperatures at the two stations differ 13°.9 while the differences of the pressures, B′—B, differ only 0.021 inch, showing that the density of the air column, and consequently the true average temperature, is very little affected by the diurnal inequality of temperature. This inequality of temperature, therefore, must take place in the strata only very near the earth's surface, where the observations are made, and only in a comparatively small degree in the strata a little above the earth's surface. The period of the inequality is too short for the upper strata to become affected much, since in clear weather they absorb and radiate but little heat, and in cloudy weather the observed diurnal range of temperature at the surface is very small.

By using the values of $\frac{1}{2}(t'+t)$ in the formula, obtained from surface observations, instead of the true temperature of the air column, we get the values of H in the preceding table, which are too small from the morning and evening observations and much too large from the observations of 2 p. m., because the value of $\frac{1}{2}(t'+t)$ is less than the average temperature of the air-column morning and evening, and much greater at 2 p. m. If the mean temperature of the day had been used throughout, instead of the observed temperatures at 7 a. m., 2 p. m., and 9 p. m., the values of H for each of the hours of observation would have differed but little. In barometric hypsometry, therefore, observations should be made at such hours of the day as will give the mean temperature of the day.

From the averages of the preceding table we have—

| Hour. | B′—B | $\frac{1}{2}(t'+t)$ | $\Delta\tau$ | $\Delta'\tau$ |
|---|---|---|---|---|
| | *Inches.* | ° | ° | ° |
| 7 a. m... | 6.742 | 45.3 | −5.5 | —0.9 |
| 2 p. m... | 6.721 | 59.2 | +8.4 | +0.3 |
| 9 p. m... | 6.714 | 48.0 | —2.8 | —0.7 |
| Mean ... | 6.726 | 50.8 | ....... | ........ |

In this table $\Delta\tau$ represents the excess of $\frac{1}{2}(t'+t)$ above the mean, and $\Delta'\tau$ represents the excess of the true average temperature of the air-column at the several hours of observation above the mean of the three, upon the hypothesis that the density of the air-column is affected only by temperature. The last two columns above indicate that the latter is very small in comparison with the former.

The same is shown from the bi-hourly observations at Geneva and St. Bernard. From the averages for the month of September, obtained from six years' observations, we get from Rühlman, p. 61, the following results:

| Hour. | B′—B | $\frac{1}{2}(t'+t)$ | $\Delta$ | $\Delta'\tau$ |
|---|---|---|---|---|
| | *mm.* | °C. | ° | ° |
| Noon .... | 160.33 | 11.7 | +2.3 | —0.1 |
| 2 h....... | 159.95 | 12.3 | 3.1 | +0.6 |
| 4 h....... | 159.68 | 11.9 | 2.7 | 1.1 |
| 6 h....... | 159.69 | 10.5 | +1.3 | 1.0 |
| 8 h....... | 160.04 | 9.2 | 0.0 | 0.4 |
| 10 h....... | 160.17 | 8.3 | —0.9 | +0.2 |
| Midnight . | 160.30 | 7.7 | 1.5 | 0.0 |
| 2 h...... | 160.38 | 6.9 | 2.3 | —0.2 |
| 4 h....... | 160.62 | 6.2 | 3.0 | 0.6 |
| 6 h....... | 160.86 | 6.5 | 2.7 | 1.0 |
| 8 h...... | 160.80 | 8.7 | —0.5 | 0.9 |
| 10 h....... | 160.65 | 10.5 | +1.3 | —0.6 |
| Mean ..... | 160.29 | 9.2 | ........ | ........ |

The numbers in this table for the hours of the latter part of the night cannot be regarded as being very exact, since they were obtained by Professor Plantamour by interpolation and not from actual observation. They are sufficiently accurate however to show, as is seen from the last two columns in the table above, that the diurnal inequality in the true average temperature of the air-column is only about one-third of that of the mean of the surface observations at Geneva and St. Bernard. They also show that the vanishing nodes and epochs of maxima and minima do not exactly coincide.

26. The following twelve-year averages (1864–1875) of barometric pressure, temperature, and relative humidity R, for the several places in Switzerland contained in the first column of the following table, are taken from the Zeit. der Oest. Gesell. für Meteorologie, B. 12, S. 116:

| Place. | Bar. | Temp. | R | Altitude. | At the level of Geneva. | | Computed altitude. |
|---|---|---|---|---|---|---|---|
| | | | | | Bar. | Temp. | |
| | *mm.* | | | *m.* | *m.* | ° | *m.* |
| St. Bernard ..... | 564. 1 | −1. 3 | (78) | 2478 | ........... | ........... | 2476 |
| Sils ............ | 612 9 | 1. 6 | 76 | 1810 | ........... | ........... | 1800 |
| Gräichen ........ | 626. 4 | 4. 2 | ........ | 1632 | ........... | ........... | 1633 |
| Chaumont ...... | 664. 6 | 5. 6 | 81 | 1150 | ........... | ........... | 1149 |
| Trogen ......... | 682. 6 | 6. 8 | ........ | 924 | 726. 5 | 9. 2 | 925 |
| Berne........... | 712. 5 | 8. 1 | 77 | 574 | 726. 8 | 9. 1 | 573 |
| Neuchâtel ...... | 719. 7 | 9. 0 | 76 | 488 | 726. 7 | 9. 4 | 492 |
| Allstäten ....... | 720. 6 | 8. 6 | 78 | 478 | 726. 7 | 9. 0 | 479 |
| Zürich.......... | 721. 5 | 8. 7 | 81 | 470 | 726. 9 | 9. 0 | 469 |
| Geneva ......... | 726. 8 | 9. 7 | 76 | 408 | 726. 8 | 9. 7 | ........... |
| Basel ........... | 738. 2 | 9. 3 | 76 | 278 | 726. 8 | 8. 6 | 281 |
| Castesegna ..... | 701. 1 | 9. 7 | 66 | 700 | 726. 1 | 11. 3 | 699 |
| Lugano ......... | 737. 4 | 11. 6 | 74 | 275 | 726. 0 | 10. 9 | 277 |

By reducing the barometer and temperature of all the stations having an altitude less than 1,000 meters to the level of Geneva, the former by the method given in §33 and the latter by the rate of $0^{\circ}.57$ per 100 meters of difference of altitude, we can determine very nearly the barometric and temperature gradients at the level of Geneva. The uncertainties in the reductions for the differences between the altitude of Geneva and the rest of these stations are very large. Neglecting very small irregularities, which may be supposed to be due to local causes, we get from these reduced pressures and temperatures the small chart, Fig. 2, showing the mean annual pressures and temperatures for all places at the level of Geneva. This chart gives for St. Bernard, at the level of Geneva, $B''=726^{mm}.5$ and $t''=10^{\circ}.6$, which have been used in the computation of the altitude of St. Bernard in § 23. The chart shows a small gradient of barometric pressure increasing in the direction of N.NW., which indicates that Switzerland is a little south of the maximum of the ridge of mean annual pressure extending from the latitude of 30° or 35° in the Atlantic Ocean over Spain and France into the interior of Asia.

It is not stated in what way the altitudes given in the preceding table have been determined, but it has been supposed here that those at least of a less altitude than 1,000 meters have been determined from actual leveling. If, however, some of them have been determined barometrically, it has no doubt been done by a comparison with some near station of which the true altitude was known, so that even in this case the gradient would not be much affected. But if all the altitudes had been determined in this way by a comparison of all the observations in all cases with those of the same place, as Geneva for instance, then in reducing the observations to this level with the altitudes thus obtained, we, of course, would not get any gradient.

The altitudes in the last column of the preceding table have been computed from the barometric, temperature, and hygrometric observations of each place and those of Geneva, the barometric and temperature observations of the latter place being in each case corrected for the effect of the barometric and temperature gradients, or, in other words, the values of $B''$ and $t''$ required in the formula were taken from the chart, Fig. 2, for the latitude and longitude of St. Bernard. There is mostly a satisfactory agreement between the given and computed altitudes, except in the case of Sils. Perhaps the given altitude was determined barometrically by a comparison of barometric observations with those of Geneva, without taking into account the effect of barometric and temperature gradients, for in this way we would obtain an altitude too great.

If all the altitudes were computed in the same way with reference to each of the other stations as has been done with reference to Geneva, of course we should in each case obtain somewhat different results, owing to the small, unavoidable inaccuracies in the observations and other data, but the errors arising from the effects of the barometric and temperature gradients would be eliminated.

27. From the same place in the Zeit. der Oes. Gesell. füi Meteorologie, from which the preceding averages have been copied, we likewise extract the following monthly averages from twelve years' observations:

| Month. | St. Bernard. | | | Geneva. | | | Basil. | | Lugano. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | B | $t$ | R | B | $t$ | R | B | $t$ | B | $t$ |
| | mm. | ° | | mm. | ° | | mm. | ° | mm. | ° |
| January | 561.1 | −8.1 | 82 | 727.5 | 0.6 | 85 | 738.8 | 0.4 | 738.7 | 1.3 |
| February | 561.7 | −7.8 | 80 | 727.9 | 2.3 | 81 | 739.3 | 2.2 | 738.7 | 5.6 |
| March | 558.7 | −7.4 | 80 | 723.8 | 4.6 | 75 | 735.6 | 4.5 | 734.5 | 6.7 |
| April | 563.0 | −2.5 | 73 | 726.1 | 9.7 | 68 | 737.6 | 9.9 | 736.6 | 12.1 |
| May | 564.8 | 1.4 | 73 | 725.9 | 13.8 | 69 | 737.4 | 13.6 | 736.7 | 15.8 |
| June | 567.4 | 4.1 | 74 | 727.6 | 16.9 | 68 | 738.9 | 16.6 | 737.3 | 19.2 |
| July | 569.0 | 7.5 | 74 | 727.5 | 19.6 | 68 | 738.5 | 19.3 | 737.3 | 22.0 |
| August | 568.5 | 6.3 | 77 | 727.7 | 18.0 | 71 | 738.7 | 17.4 | 737.4 | 20.4 |
| September | 568.7 | 5.0 | 79 | 728.4 | 15.8 | 75 | 739.5 | 15.0 | 739.3 | 17.8 |
| October | 564.0 | −0.8 | 83 | 726.1 | 9.7 | 81 | 737.3 | 8.9 | 737.3 | 11.7 |
| November | 561.4 | −5.4 | 83 | 726.1 | 4.6 | 82 | 737.5 | 4.1 | 736.8 | 6.4 |
| December | 560.9 | −7.7 | 81 | 727.2 | 0.5 | 86 | 738.7 | −0.2 | 737.7 | 2.9 |

The values of R for St. Bernard are not given, and the ones here given, to be used in the computations, are the averages of Sils and Chaumont.

By comparing the values of B and $t$ for Basil and Lugano, which are on opposite sides of the chart, Fig. 2, it is seen that the barometric and temperature gradients have only a very small annual inequality, the changes from month to month being mostly due to small uneliminated errors in the monthly averages. We may therefore assume, without material error, that the gradients are the same for all months of the year, and shall, therefore, as in the computations from the yearly averages in §23, deduct the constant $0^{mm}.3$ from the barometer at Geneva to get the pressure at St. Bernard reduced to the level of Geneva, and add 0°.8 to the monthly values of $t$ at Geneva to get the value of the temperature at St. Bernard reduced to the level of Geneva. This is supposed to give the temperature $t''$ required in the formula much more accurately than it could be obtained from reducing the observed temperature at St. Bernard, through so great a difference of altitude, to the level of Geneva by any observed rate of increase of temperature with decrease of altitude.

With the preceding reductions for the effects of the barometric and temperature gradients, we get the following data for computing the difference of the altitude between Geneva and St. Bernard from each of the monthly averages of the observations:

| Month. | Monthly averages. | | | | Results. | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | B″ | B | $t''$ | $t$ | H | $\Delta$ | $\Delta'$ | $t''-t$ | Change of $t$ per $100^m$. | $e$ | $e'$ |
| | mm. | mm. | ° | ° | m. | m. | m. | ° | ° | m. | m. |
| January | 727.2 | 561.1 | 1.4 | −8.1 | 2056.0 | −11.6 | −9.7 | 9.5 | 0.46 | 0.0 | −6.0 |
| February | 727.6 | 561.7 | 3.1 | −7.8 | 2060.0 | −7.6 | 7.1 | 10.9 | 0.53 | 0.0 | 5.6 |
| March | 723.5 | 558.7 | 5.4 | −7.4 | 2068.1 | +0.5 | −2.6 | 12.8 | 0.62 | +0.1 | 5.0 |
| April | 725.8 | 563.0 | 10.5 | −2.5 | 2070.7 | 3.1 | +2.6 | 13.0 | 0.63 | 0.9 | 2.6 |
| May | 727.6 | 564.8 | 14.6 | 1.4 | 2073.8 | 6.2 | 7.1 | 13.2 | 0.64 | 2.2 | 2.8 |
| June | 727.3 | 567.4 | 17.7 | 4.1 | 2077.8 | 11.2 | 9.7 | 13.6 | 0.66 | 1.5 | 1.1 |
| July | 727.2 | 569.0 | 20.4 | 7.5 | 2077.1 | 9.5 | 9.7 | 12.9 | 0.62 | 2.3 | 0.9 |
| August | 727.4 | 568.5 | 18.8 | 6.3 | 2076.0 | 8.4 | 7.1 | 12.5 | 0.60 | 1.8 | 1.3 |
| September | 728.1 | 568.7 | 16.6 | 5.0 | 2067.8 | +0.2 | +2.6 | 11.6 | 0.56 | +1.3 | 1.8 |
| October | 725.8 | 564.0 | 10.5 | −0.8 | 2063.8 | −3.8 | −2.6 | 11.3 | 0.55 | 0.0 | 3.4 |
| November | 725.8 | 561.4 | 5.4 | −5.4 | 2063.2 | 4.4 | 7.1 | 10.8 | 0.53 | 0.0 | 4.6 |
| December | 726.9 | 560.9 | 1.3 | −7.7 | 2057.0 | −10.6 | −9.7 | 9.0 | 0.44 | −0.3 | −6.3 |
| Year | 726.5 | 564.1 | 10.6 | −1.3 | 2067.6 | ........ | ........ | 11.8 | 0.57 | +0.8 | −3.5 |

The relative humidities R′ and R of the lower and upper stations, respectively, to be used in the computations of H are contained in the preceding table. By computing with these data, as in the example in §23, from the yearly averages, we get the several values of H above from each set of monthly averages of the observations. The average of the monthly values, $2067^{m}.6$, differs from the true difference of altitude, $2070^{m}$, determined by leveling, only 2.4 meters, and from the value in §23, computed from the yearly averages, it differs $0^{m}.6$. The reason of this latter difference has been given in the case of Sacramento and Summit in §25.

The values of $\Delta$ above show that there is an annual inequality in the values of H computed from the monthly averages of observations, just as in the case of Sacramento and Summit, which is to be explained in the same way. If we suppose the most probable values of H given by the formula, independent of all abnormal irregularities, to be represented by the expression of H given in §25, we get $B=10^{m}.0$, and $E=178^{\circ}.1$. This value of E indicates that the maxima and minima of H occur about the 1st of July and January, respectively, and the vanishing epochs of $\Delta$ about the 1st of April and October. These epochs, therefore, are a month later than in the case of Sacramento and Summit. With these values of B and E in the expression of H, § 25, we get the most probable values of H, to which correspond the values of $\Delta'$, which are the true monthly values of the annual inequality with the effects of the abnormal irregularities eliminated.

The mean rate of decrease of temperature with increase of altitude is considerably greater in this case than in that of Sacramento and Summit, and the annual inequality in this rate is also greater. The epochs of maximum and minimum also occur later, as in the case of the values of H.

If no hygrometric observations had been made, and Table IV had been used instead of Tables II and III, the values of H in the preceding table would have been increased by the amounts contained in the column *e*. These are all positive with one exception, and indicate that the vapor correction given by Table IV is a little too large for the higher temperatures. This is, no doubt, the case for high altitudes in mountainous regions, but not so generally, for, the temperature being the same, the amount of vapor in the air near the ocean is greater than in the interior of continents. Table IV, based upon Dr. Hann's empirical expression of the most probable or average value of the amount of vapor in the atmosphere, except for the lower temperatures, is, no doubt, as correct for general application under all circumstances as it can be made where the amount of vapor is regarded as a function of the temperature simply.

The last column in the preceding table, headed $e'$, gives the errors which would have resulted if the effect of the aqueous vapor in the air had been taken into account by means of Laplace's modified temperature coefficient in the formula (25), .002 instead of .00183. It is seen that the errors throughout are negative and quite large for the low temperatures of the winter season, but small for the higher temperatures of the summer season.

28. From the reports of the Chief Signal Officer, United States Army, the following monthly and yearly averages of the values of $B''$, $B$, and $t''$, $t$ are obtained from the monthly averages of observations made at Portland, Burlington, and the top of Mount Washington. The latitude of Mount Washington is 44° 16′, and the relative positions of the three places are shown by Fig. 3. The barometric pressures given are reduced to sea-level. These show that there is a small gradient of pressure increasing in the direction from Portland toward Burlington in the winter, and the reverse in summer. As Mount Washington is nearly on a right line from Portland to Burlington, and at about two-fifths of the distance, two-fifths of the difference between the pressure at Burlington and Portland have been added to that of the latter in order to eliminate the effect of the gradient, and thus the values of $B''$ have been obtained. The pressures on the top of Mount Washington were reduced to sea-level by means of the constant 6.31 inches from October, 1871, to March, 1874, and after that by the constant 6.36 inches. These constants have been deducted in order to get the values of B in the following table. The temperatures were reduced to sea-level and the effect of a temperature gradient eliminated in the same way as in the case of the barometric pressures. In

this way the following monthly averages were obtained as data for computing the height of Mount Washington:

| Month. | Monthly averages. | | | | Results. | | | |
|---|---|---|---|---|---|---|---|---|
| | $B''$ | $B$ | $t''$ | $t$ | $H$ | $\Delta$ | $\Delta'$ | Decrease of $t$ per $100^m$. |
| | *Inches.* | *Inches.* | ° | ° | *Feet.* | *Feet.* | *Feet.* | °C. |
| January | 30.050 | 23.385 | 21.1 | 5.3 | 6348 | +22 | +27 | 0.47 |
| February | 29.979 | 23.354 | 23.0 | 5.6 | 6338 | 11 | 21 | 0.54 |
| March | 29.928 | 23.376 | 28.4 | 9.7 | 6335 | + 8 | + 9 | 0.53 |
| April | 29.930 | 23.534 | 41.4 | 20.1 | 6325 | − 2 | − 4 | 0.62 |
| May | 29.936 | 23.700 | 54.2 | 32.2 | 6305 | 21 | 16 | 0.63 |
| June | 29.929 | 23.814 | 65.0 | 44.0 | 6321 | 6 | 25 | 0.57 |
| July | 29.931 | 23.886 | 70.0 | 47.7 | 6296 | 30 | 27 | 0.61 |
| August | 30.009 | 23.943 | 69.9 | 47.3 | 6299 | 28 | 21 | 0.60 |
| September | 30.004 | 23.830 | 59.5 | 39.3 | 6311 | −15 | − 9 | 0.58 |
| October | 29.995 | 23.666 | 48.7 | 28.9 | 6337 | +10 | + 4 | 0.56 |
| November | 29.967 | 23.497 | 34.1 | 15.5 | 6312 | −14 | 16 | 0.55 |
| December | 30.000 | 23.325 | 23.3 | 6.4 | 6391 | +64 | +25 | 0.50 |
| Year | 29.971 | 23.609 | 44.7 | 25.2 | 6326.5 | ...... | ...... | 0.563 |

As the hygrometric observations are not given, the computations must be made, as in the case of Sacramento and Summit, by using Table IV instead of Tables II and III. We thus obtain the monthly values of H above. The mean of these is 6,326.5 feet. Two lines have been run with the spirit-level from the railroad station at Gorham to the top of Mount Washington, the first by W. A. Goodwin, civil engineer, in August, 1852, and the second by Capt. T. J. Cram, of the Topographical Engineers, for the Coast Survey, in September, 1853. From the first the top of Mount Washington was determined to be 6,285.5 feet above sea-level, and from the latter 6,293 feet. The mean of these is 6,289 feet. The preceding result, therefore, obtained barometrically, seems to be about 37 feet too great. By the same formula we have seen that the altitude obtained for Summit above Sacramento was 24 feet less than that obtained from the railroad survey.

From the values of $\Delta$, or the most probable values $\Delta'$, in the preceding results, it is seen that here also we have an annual inequality in the values of H given by the formula, but we have the unusual result of the maximum of H occurring in the winter instead of summer. This indicates that the values of $\frac{1}{2}(t''+t)$ are greater than the average temperature of the air column in winter and smaller in summer, just the reverse of what is required to explain the discrepancies in all the other cases we have examined. This is probably due to the fact that at both of the lower stations, Portland on the sea-coast and Burlington on the east side of Lake Champlain, the thermometer was near a large body of water, which lowered the temperature in its vicinity in the summer and increased it in the winter, and thus made the value of $\frac{1}{2}(t''+t)$ too small in summer and too great in winter to represent the average temperature of the air above the earth's surface. The same would have occurred in the case of Summit, in California, if the barometric observations had been compared with those of San Francisco instead of Sacramento. At the former place the range of temperature is less than 8° Fahr., while at the latter it is about 27°. Hence the summer temperatures of San Francisco are nearly 10° less, and the winter temperatures as much greater than at Sacramento, while the difference in the pressures of the two places at the same level is very small. With the temperature observations, therefore, of San Francisco instead of Sacramento, we should have had the value of $\frac{1}{2}(t'+t)$ nearly 5° greater in winter and the same amount less in summer. This would have completely reversed the signs of the values of $\Delta$ in § 25, and given values of H having a very large annual inequality with its maximum in the winter instead of the summer, as in the case of Mount Washington.

Treating the values of $\Delta$ as in the preceding cases, we get B=26° and E=6°.4. The latter indicates that the maximum of H, with abnormal irregularities eliminated, occurs about the 6th of January, and the mean values, or vanishing epochs of $\Delta$, about the 6th of April and October. These epochs are nearly the same as in the case of Geneva and St. Bernard, but the whole inequality is reversed. The rate of decrease of temperature with increase of altitude is very nearly the same as in Switzerland, both in the annual mean and for the several months of the year.

29. Finally, we have in the Boletin de la Sociedad Mexicana de Geographia y Estadistica, Tomo iv, p. 216, 1878, the following monthly averages of observations made three times a day for one year at Vera Cruz, latitude 19° 11′, and the city of Mexico, latitude 19° 25′, and longitude 99° 5′ W.:

| Year and month. | Monthly averages. | | | | Results. | | |
|---|---|---|---|---|---|---|---|
| | $B'$ | $B$ | $t'$ | $t$ | $H$ | $\Delta$ | Decrease of *t* per 100$^{m}$ |
| 1877. | mm. | mm. | ° | ° | m. | m. | ° |
| July | 760. 90 | 568. 88 | 29. 1 | 17. 5 | 2278. 7 | − 0. 9 | 0. 51 |
| August | 761. 44 | 587. 61 | 29. 9 | 17. 5 | 2287. 4 | + 7. 8 | 0. 54 |
| September | 760. 22 | 586. 65 | 29. 2 | 16. 5 | 2276. 6 | − 3. 0 | 0. 56 |
| October | 760. 63 | 587. 13 | 28. 8 | 16. 6 | 2272. 9 | − 6. 7 | 0. 52 |
| November | 763. 11 | 586. 95 | 25. 5 | 14. 1 | 2279. 4 | − 0. 2 | 0. 50 |
| December | 764. 30 | 586. 78 | 22. 7 | 12. 4 | 2276. 0 | − 3. 6 | 0. 45 |
| 1878. | | | | | | | |
| January | 764. 23 | 586. 34 | 20. 9 | 12. 9 | 2276. 4 | − 3. 2 | 0. 33 |
| February | 761. 60 | 585. 57 | 22. 2 | 14. 1 | 2268. 4 | −11. 2 | 0. 36 |
| March | 760. 87 | 585. 89 | 24. 3 | 16. 2 | 2273. 3 | − 6. 3 | 0. 36 |
| April | 756. 99 | 584. 80 | 26. 9 | 19. 9 | 2306. 0 | +26. 4 | 0. 31 |
| May | 759. 21 | 586. 62 | 29. 0 | 19. 7 | 2278. 1 | − 1. 5 | 0. 41 |
| June | 759. 49 | 586. 72 | 30. 5 | 18. 9 | 2282 6 | + 3. 0 | 0. 51 |
| Mean | ........ | ........ | ...... | ...... | 2279. 6 | ... ... | 0. 45 |

The monthly values of H here are a little more irregular than in the preceding cases, on account of there being only one year's observations from which to get the averages. The range of temperature being small, the annual inequality in the values of H is also small, and scarcely perceptible amidst the abnormal irregularities. The city of Mexico is about 250 miles west of Vera Cruz, but notwithstanding the distance there is perhaps very little barometric or temperature gradient between the two places, so that $B'$ and $t'$ can be used for $B''$ and $t''$ without much error.

The barometer at Vera Cruz was 7.8 meters above sea-level. This, added to the mean value of H above, gives 2,287.4 meters for the altitude of the barometer at the city of Mexico above sea-level. The true altitude from railroad surveys is 2,282.5 meters, being nearly five meters less than the computed altitude. The rate of decrease of temperature with increase of altitude is very nearly the same as in California. The maximum rate is in the fall and the minimum in the spring, and the range of inequality large.

30. From the preceding comparisons it is seen that the excess of altitude given by the formula over that obtained from actual leveling is, for

| | |
|---|---|
| Sacramento and Summit, 3 years' observations, | −24 feet. |
| Geneva and St. Bernard, 12 years' observations, | −2.6 meters. |
| Portland and Mount Washington, 6 years' observations, | +37 feet. |
| Vera Cruz and city of Mexico, 1 year's observations, | + 5 meters. |

These results do not indicate that high degree of accuracy in barometric hypsometry, even where a long series of observations is used, which was formerly supposed to be attainable by this means. In these comparisons that of Geneva and St. Bernard should have the most weight, both on account of the long-continued series of observations upon which the result is based, and also the great care with which the observations have been made. The observations have been regularly made for about forty years, and the result obtained from the whole series differs very little from that of the twelve years here used. The signs, however, of the differences between the altitudes given by the formula and those obtained by leveling, one half being plus and the other half minus, do not indicate any error in the principal constant of the formula, considering the greater weight which the comparison for Geneva and St. Bernard should have.

In the comparisons of the results from monthly averages, we have seen that the differences between the true altitude and those given by the formula are still greater, especially at certain seasons of the year, since there is an annual inequality in the results given by the formula, due to errors in obtaining the true temperature of the air column. We have also seen that there is a diurnal inequality of the same sort, even greater than the annual. These inequalities do not only differ in range at different places, and, in the case of the annual inequality at least, become entirely reversed, but the epochs of maxima and minima and of the vanishing nodes of the inequalities also differ considerably at different places. For Sacramento and Summit the latter occur the 1st of March and September, but for Geneva and St. Bernard on the 1st of April and September, and for Portland and Mount Washington still a few days later. It is probable that these epochs are nearly the same for the same country as for California or Switzerland, and if so, and these epochs have been determined, where only a few or a short series of observations are made for hypsometric purposes in any country, they should be made at or near the times of these epochs, or at least so taken that the effect of the annual inequality will be eliminated from the result. From what we have seen it would be useless to attempt to give tables of corrections for this inequality, as has been done in a few instances, which would be applicable even within a very limited range of country, for we have seen that the range of this inequality may not only change very much, but that in California it may become entirely reversed by referring Summit to San Francisco instead of Sacramento.

The effect of the diurnal inequality can be very nearly eliminated by taking the observations at such hour or hours of the day as will give the mean temperature of the day, but if these observations should be taken near either of the extremes of temperature, as the early morning or the afternoon, the results cannot be relied on, as is seen from the results given in the table of §25 in the case of Sacramento and Summit. In fact, at whatever hour of the day the barometric observations may be made it is much better to use the mean temperature of the day with them than the extreme temperatures. Where only a few observations are used those are best which are made at times when there is little diurnal change in the temperature, and when the diurnal average differs but little from the monthly average or normal temperature of the time of year. Such observations should not be taken when the air is foggy or misty, since the weight of the air is increased by the particles of fog or mist in it.

31. The variation of the true from the observed temperatures in the monthly averages arises from the fact that the annual range of temperature is less in the open air at some distance from the earth's surface than it is at the surface. The longer the period of the inequality the more nearly the temperatures should agree. While in the annual inequalities the variations of the true from the observed is generally only from about one-fifth to one-tenth of the whole amplitude of the inequalities, in the diurnal inequality it amounts to the greater part of it, the temperature of the upper strata undergoing but little change in comparison with that of the observed temperatures at the earth's surface.

In the numerous abnormal changes of temperature with periods of one to two weeks, the amplitudes of the changes in the air at some altitude above the surface must be less than those of the observed temperatures at the surface, but the differences must be less in proportion to the whole change than in the case of the diurnal changes, and greater than in the case of the annual changes of temperature. In barometric hypsometry, therefore, where the observed temperatures differ very much from the average normal temperature of the time of year at which they are made we will get better results, where only a few observations are used, by not using the extreme temperature, but some one intermediate between the observed and the normal temperature, just as in the case of monthly averages we get better results for the months of extreme temperatures by using temperatures which deviate a little less from the mean temperature of the year than the monthly averages of temperatures observed at the earth's surface.

In order to avoid the errors arising from using the extremes of the abnormal irregularities of temperature it is best to use the normal temperature for the lower station, obtained from monthly isothermal charts, where such are at hand, or from a table of monthly normals for the vicinity, which will be equivalent to supposing that the range of the true temperature of the air column in these abnormal irregularities of short period is only half as much as that of the observed surface temperatures, or even less, since the range of these abnormal inequalities is generally less at the upper than at the lower station.

32. The principal part of the difference between the true and observed temperature of the air column where only a few observations are used, arises from assuming that there is a regular decrease of temperature with increase of altitude. This may be nearly so in yearly, and even in monthly, averages, but we know that, for various reasons, the variations from this law are, at any given time, so great that the temperature may increase instead of decrease as you ascend, and, where the difference of altitude is considerable, the true mean temperature of the air column may differ from the mean of the observed temperatures of the two stations several degrees of Fahrenheit. Each one of these would affect the computed difference of altitude the $\frac{1}{491}$ part, and hence would give rise to large errors.

A large part of the errors in barometric hypsometry, where only a few observations are used, and the true stations are a considerable distance apart, arises from the local and temporary barometric gradients, depending upon the various cyclonic disturbances of the atmosphere. If the stations were several hundred miles apart, an ordinary gradient, such as occurs frequently without a great storm, might affect the result a hundred feet or more.

The differences of altitude, therefore, from one or even several days' observations cannot be relied upon as being more than a rough approximation to the true difference. This has been shown by Williamson, who has computed the difference of altitude between Geneva and St. Bernard from the observations for every day of the year 1862. These differ from the true difference of altitude, in some extreme cases, more than 60 meters. In these extreme cases, which occur mostly in the winter, the results were no doubt affected by the barometer gradients.

33. The last member of (35), taken positively, expresses the height of a column of air in meters corresponding to one millimeter in the barometer on the parallel of 45°. Reducing this to English measures we get for the expression in feet of such a column corresponding to one-tenth of an inch of the barometer,

$$\delta\mathrm{H}=\frac{2632.5}{\mathrm{B}}\,[1+.002222\,(t-32^\circ)]$$

This expression is adapted to the average hygrometric state of the atmosphere, and for this purpose it can be made a little more accurate by introducing the value of $1+f(e)$, of which the logarithm is given in Table IV, instead of that given in § 17. With this change we get

$$\delta\mathrm{H}=\frac{2628.4}{\mathrm{B}}\,[1+.002034\,(t-32^\circ)]\,[1+f(e)]$$

As the last factor of this expression, as given in Table IV, is a function of the temperature, it has only the variables B and $t$. From this expression, with the use of this table, the values of $\delta$H have been computed for short intervals within certain limits of the two arguments B and $t$, and given in Table XIII. The differences between this table and Guyot's arise from its having been computed with the improved constants in the barometric formula, based upon the more recent and accurate determination by Regnault of the constants of nature upon which they depend, instead of the constants of Laplace's formula.

This table may be used in computing differences of altitudes without the use of logarithms, as follows: Take first the number from the table corresponding to the arguments B$''$ and $t''$, then the number corresponding to the arguments B and $t$, and finally the number corresponding to the arguments $\frac{1}{2}$(B$''$+B) and $\frac{1}{2}(t''+t)$. Then take one-fifth of the sum of the first two and three times the latter and multiply this into (B$''$−B), expressed in tenths of an inch, for the value of H in feet. Let us apply it to the example of Sacramento and Summit, given in § 24. The table gives for the arguments, using from necessity base B$'$ and $t'$ for B$''$ and $t'$,

| *Inches.* ° | |
|---|---|
| $\mathrm{B}'=30.014$ and $t'=59.9$, | 93.19 |
| $\mathrm{B}\ =23.288$ and $t=42.1$, | 115.56 |
| $\frac{1}{2}(\mathrm{B}'+\mathrm{B})=26.651$ and $\frac{1}{2}(t'+t)=51^\circ$, | $102.95\times 3=308.85$ |
| | $5\overline{)517.60}$ |
| | 103.52 |

$$\mathrm{H}\ =(\mathrm{B}'-\mathrm{B})\times 103.52=67.26\times 103.52=6963 \text{ feet.}$$

This value of H is only 3 feet less than that obtained in § 24. For much smaller differences of altitude it is only necessary to take out the number corresponding to the last two arguments, and to use this instead of the mean of the five. In the example above this would give $H=67.26\times 102.95=6925$, but the error diminishes very rapidly with decrease of difference of altitude, and for a thousand feet or more is of no consequence.

In Table XII the effect of the last two factors in the formula (25) is not taken into account, so that it is strictly correct for the parallel of 45° and sea-level. But the effect of these two terms in the middle latitudes is very small. Their effect upon the difference of altitude between Sacramento and Summit, nearly 7,000 feet, is only about 6 feet, and proportionally in the same latitude for smaller differences of altitude. The extreme effect of the factor depending upon the latitude, which is at the equator and the pole only $\frac{1}{384}$ of the whole difference of altitude. At the equator the values in Table XII are too small, and at the pole too large, in that proportion.

In order to have all the tables necessary in barometric hypsometry, Table XIII is added, which is reduced to English measures from Delcros's table.

## CHAPTER III.

## REDUCTION OF THE BAROMETER TO SEA-LEVEL.

33. In order to form a chart of isobars, showing the barometric gradients and the general distribution of pressure from barometric observations at different altitudes, it is necessary to reduce all these observations to some assumed level, which is generally that of sea-level. This is a problem somewhat the reverse of that of determining the difference of altitude of two stations from observations made at the two levels. The same equation (25) must be satisfied in both cases, but in the one H is the unknown quantity to be determined, and in the other B″, either of which can be determined when all the other quantities in the equation are known.

In the uncertainties of reduction to sea-level both of the last factors in (25), at least in the middle latitudes, may be neglected, and the whole effect of the factor for the vapor correction is so small that it is only necessary to use its average or most probable value, taken over the earth generally, for any given temperature, neglecting its variations at different times and localities. By so doing we have seen, § 27, that in the case of St. Bernard the greatest error in computing the altitude from the monthly averages of observations amounted to only 2.3 meters, or 7.5 feet, which at ordinary temperatures, as is seen from Table XII, correspond to only about 0.008 inch of barometric pressure.

We, therefore, get from (25), reduced to English measures,

$$\log B''=\log B+\frac{H}{60521.5\,[1+.001017\,(t''+t-64^\circ)]\,[1+f\,(e)]}$$

in which $[1+f\,(e)]$, represents, as in § 32, the average value of this factor regarded as a function of $t$, the logarithm of which is contained in Table IV. This expression may be put into the following form:

$$(a)\qquad \log B''=\log B+R$$

in which

$$(b)\qquad \log R\ =\log H-(\text{Table 1}+\text{Table IV})$$

Where it is thought necessary, all the other tables can be used in this expression, just as in the computation of differences of altitude. For French measures the constant logarithm 0.51599 must be added to the expression of log R, and the tables must be entered with $\frac{9}{5}(t''+t)+64^\circ$ as an argument.

As an example of the application of these formulæ, let it be required to reduce the mean barometric pressure on the top of Mount Washington to sea-level. In this example we have, from the table of § 28, $B=23.609$ inches, $t''+t=69^\circ.9$, and the value of $H=6289$ feet.

Hence, we have

| | | | |
|---|---|---|---|
| Log H | $=3.79858$ | R | $=0.10303$ |
| Table I, with arg. 69°.9, | $=4.78451$ | log B | $=1.37308$ |
| Table IV, with arg. 69°.9, | $=0.00110$ | log $B''$ | $=1.47611$ |
| | $4.78561$ | $B''$ | $=29.930$ inches. |
| Log R | $=9.01297$ | | |

As an example of application in the case of French measures, let it be required to reduce the mean pressure at St. Bernard to the level of Geneva. We have in this case, from § 23, $B=564^{mm}.1$, $t''+t=9^\circ.3$, and $H=2070^{m}$. Hence we have

| | | | |
|---|---|---|---|
| Log H | $=3.31597$ | R | $=0.10992$ |
| Table I, arg. $\frac{9}{5}\times 9^\circ.3+64^\circ=80^\circ.7$, | $=4.78923$ | log B | $=2.75136$ |
| Table IV, arg. $\frac{9}{5}\times 9^\circ.3+64^\circ=80^\circ.7$, | $=0.00164$ | log $B''$ | $=2.86128$ |
| | $4.79087$ | $B''$ | $=726^{mm}.6$ |
| | $8.52510$ | | |
| Constant log | $0.51599$ | | |
| Log R | $=9.04109$ | | |

34. Where $\frac{1}{2}(t''+t)$, as is usually the case, does not represent the true average temperature of the air column, of course we do not get the true reduction to sea-level, as in the computation of altitudes we get an erroneous result when this is the case. Where the correction of $t''+t$ is known, it can be applied to the argument, or where the errors in the values of H, as computed from yearly and monthly averages of observations are known, as in the case of Mount Washington and St. Bernard, these can be added to the true value of H, and then the formula will give the true reduction to sea-level, with $t''+t$ used as the true temperature. Putting

$$\Delta H=\text{the excess of the true over the computed value of H}$$

we shall have in place of (*b*)

$$\text{Log R}=\log(H+\Delta H)-(\text{Table I}+\text{Table IV}) \qquad (c)$$

The value of $t''$ at sea-level for yearly and monthly averages may be determined for any given station, as has been done in § 27 in the case of St. Bernard for the yearly average at the level of Geneva, by means of temperature charts of which the small chart, Fig. 2, is a specimen. But for individual observations or short series of observations, made at any time of year or hour of the day, the value of $t''$ cannot be determined in this way. In such cases it is usual to put

$$t''=t+cH$$

in which $c$ represents the rate of increase of temperature with decrease of elevation. But $c$ is by no means a constant, as we have seen, for it is different for different localities and seasons, and also at different altitudes, even where we have the average rate for a large number of observations. In individual cases not only is $c$ in the preceding expression entirely unknown, but so great are the anomalies in the vertical distribution of temperature that the law of the expression entirely fails. The value of $c$ is sometimes assumed to be a constant for all places and seasons, but this leads to great errors in reductions to sea-level at the seasons of extreme temperature. Take, for instance, the case of Salt Lake City, about 4,400 feet above the sea-level. The average temperature of July here is greater than that of the plateau between the Missouri River and the Rocky Mountains, with an average elevation about 3,000 feet less. We have seen that the value of $t$ required in barometric hypsometry, and the same is the case here, is the temperature of the air generally around the mountain at the same elevation, and not the temperature observed at the heated surface of a mountain or in some elevated mountain valley. The observed value of $t$, then, is too great in such a case to represent the temperature of the air generally at the altitude of the observation, and it is readily seen that if this temperature is reduced to sea-level according to the preceding formula, with any average value of $c$ for all seasons and places, we get a value of $t''$ which makes $\frac{1}{2}(t''+t)$ much too large in this case to represent the true temperature of the air generally away from the superheated surface of the earth or mountain; for both $t''$ and $t$ are much greater than the temperature of the air generally at the respective levels of the sea and of the upper station.

35. The mean annual inequality of the error in the reductions to sea-level arising from these erroneous temperatures is corrected in ($c$) by means of $\Delta$ H, where the monthly values of $\Delta$ H have been determined, as at St. Bernard and Mount Washington, from computations of altitudes with the monthly averages of B'' and $t''$ determined from observations made at two or a number of surrounding stations. The mean diurnal inequality in the error of reduction to sea-level might be corrected in the same way if we had hourly observations to determine the diurnal inequality in the values of $\Delta$ H. We have seen in the case of Summit, in California, § 25, that this inequality is very large, and consequently the errors in reduction to sea-level must be very great where the extreme temperatures of the day are used. In fact it is seen from the comparisons of $\Delta\,\tau$ with $\Delta'\,\tau$, in the tables of § 25, that the range of the diurnal inequality in the true temperature of the air column is very small in comparison with that of the observed temperatures of the two stations, and hence the temperature which should be used in the case of the extreme temperatures of the day should deviate very little from the mean temperature of the day, and this is especially the case for Summit. Where the observed temperatures deviate from the mean of the day, so far as we now know from the investigation of only two cases, it would be best to add only one-fourth of this deviation to the mean temperature of the day, excluding the effect of the other three-fourths, where there are any means of determining this mean temperature. At any rate the extreme temperatures of the day, especially when the diurnal range is great, must not be used, if we even have to rely simply upon an exercise of good judgment in determining what temperature should be used.

In order to avoid the errors from using the extremes of the abnormal inequalities, it will be best in reductions to sea-level, as in barometric hypsometry, to use for $t''$ its normal value for the season of the year, obtained from the monthly normals, as explained in § 31. This will diminish the effect of these observed deviations from the normal temperature one-half or more, and make it generally correspond very nearly with what would be given by the true average temperature of the air column.

36. Since B'', in the expression of ($a$), is a function of three variables, B, H, and $(t''+t)$, it is not convenient to give tables for obtaining its value under all circumstances, unless the tables are very much expanded. Where, however, reductions to sea-level are required to be continually made for the same station, as in the Weather Bureau of the Signal Service, H, with regard to this station, becomes a constant, and the expression of B'' can be reduced to a linear function of only two variables, and hence requiring only two tables with a single argument each. These are increased to three where we use ($c$) instead of ($b$), in order to correct for the annual inequality of the error from using $\frac{1}{2}(t''+t)$ for the true temperature.

For the same station we can put

$$(d)\qquad B=B_0+\Delta B$$

in which $B_0$ is a value of B, in round numbers for convenience, which is nearly an average value of B in its abnormal fluctuations from various causes. We can then put

$$(e)\qquad B''=B''_0+\Delta B''$$

in which

$$(f)\qquad \begin{cases} \log B''_0=\log B_0+R \\ \log R\ \ =\log H-(\text{Table I}+\text{Table IV}) \end{cases}$$

We get from the differentiation of ($a$), or its equivalent preceding, where $\Delta$B and $\Delta$H are quantities of a second order so small that quantities of lower orders may be neglected,

$$\Delta B''=\frac{B''_0}{B_0}B\Delta+\frac{\Delta H}{60521.5\ M[1+.001017(t''+t-64^\circ)]\,[1+f(e)]}$$

in which M is the modulus of common logarithms.

This expression of $\Delta B''$ in ($e$) gives

$$(g)\qquad B''=B''_0+\frac{B''_0}{B_0}\Delta B+\frac{\Delta H}{60521.5\ M[1+.001017(t''+t-64^\circ)]\,[1+f(e)]}$$

The last term of this expression comes in where a value of H a little different from the true value is required, in order to correct for error in assuming that $\frac{1}{2}(t''+t)$ is the true temperature to be used in the formula.

The first term of this expression is given by ($f$), from which it is seen that it is a function of only one variable $(t''+t)$ entering into the arguments of the tables, $B_0$ and H being known constant quantities for any given station. Hence, $B''_0$ is readily given by a table with $t''+t$ as an argument.

The coefficient of $\Delta B$ in the second term of ($g$) is not strictly a constant, since the value of $B''_0$ in ($f$) depends upon the temperature; but by using the mean value of $B''_0$ it may be regarded as a constant without material error except in some extreme cases in which the variations of both B and the temperature from their mean values are very great. This term, then, can be reduced to a small table with $\Delta B$ as an argument. Or, if thought necessary, the variable value of $B''_0$ can be used, and a small table can be formed having $\Delta B$ and $(t''+t)$ as arguments.

The last term in ($g$) is also a function of the temperature, but this term is so small that the mean value of $(t''+t)$ in the denominator may be used without sensible error. When $\Delta H$ is known this can be reduced to a small table, with $\Delta H$ as an argument. In general only the mean monthly values of $\Delta H$ are known for any station, determined as in the preceding sections for Summit, Mount Washington, and St. Bernard. In such cases only the mean annual inequality in the value of $B''_0$, arising from errors of temperature, can be taken into account, and all the remaining part depending upon the irregular abnormal disturbances must necessarily be neglected. Using the monthly values of $\Delta H$, a small table can be formed with the time of the year as an argument. Where the value of $\Delta H$ has not been determined for any station, of course this inequality can be determined in a more direct way by reducing by means of ($a$) and ($b$) the monthly values of B to sea-level, and then comparing them with the true monthly values of B'', determined, as in the case of St. Bernard for the level of Geneva, by means of monthly charts of barometric pressure similar to that of Fig. 2.

37. The following is a specimen of such a set of tables, made in the case of St. Bernard to reduce barometric observations to the level of Geneva. The values of $\Delta H$, used in the last term of ($g$), are the differences between the computed values in the table of § 27 and the true value, 2,070 meters. In order to get rid of the abnormal irregularities in these values, $2067.6+\Delta'$ have been used for the most probable values of H. The value of $B_0$ in ($d$) has been assumed to be $560^{mm}$, which is nearly its mean value.

TABLE I.

| $t''+t$ | $B''_0$ | Diff. |
|---|---|---|
| °C. | *mm.* | |
| − 20 | 732.0 | − 1.8 |
| 15 | 731.2 | 1.9 |
| 10 | 728.3 | 1.8 |
| − 5 | 726.5 | 1.8 |
| 0 | 724.7 | 1.8 |
| + 5 | 722.9 | 1.8 |
| 10 | 721.1 | 1.8 |
| 15 | 719.3 | 1.7 |
| 20 | 717.6 | 1.7 |
| 25 | 715.9 | 1.6 |
| 30 | 714.3 | 1.7 |
| 35 | 712.6 | 1.6 |
| 40 | 711.0 | 1.6 |
| 45 | 709.4 | 1.5 |
| 50 | 707.9 | 1.5 |
| 55 | 706.4 | 1.5 |
| + 60 | 704.9 | |

TABLE II.

| $\Delta B$ | Correction. |
|---|---|
| *mm.* | *mm.* |
| 1 | 1.3 |
| 2 | 2.6 |
| 3 | 3.9 |
| 4 | 5.2 |
| 5 | 6.6 |
| 6 | 7.9 |
| 7 | 9.2 |
| 8 | 10.5 |
| 9 | 11.9 |
| 10 | 13.2 |
| 11 | 14.5 |
| 12 | 15.8 |
| 13 | 17.1 |
| 14 | 18.4 |
| 15 | 19.8 |
| 16 | 21.1 |
| 17 | 22.4 |

TABLE III.

| Month. | Correction. | |
|---|---|---|
| | *m.* | °C. |
| January | − 1.5 | 1.4 |
| February | 1.2 | 3.1 |
| March | − 0.6 | 5.4 |
| April | 0.0 | 10.5 |
| May | + 0.6 | 14.6 |
| June | 0.9 | 17.7 |
| July | 0.9 | 20.4 |
| August | + 0.6 | 18.8 |
| September | 8.0 | 16.6 |
| October | − 0.6 | 10.5 |
| November | 1.2 | 5.4 |
| December | − 1.5 | 1.3 |
| Year | 0.3 | 10.6 |

When $\Delta$B in Table II is negative, the correction is also negative.

In connection with Table III the mean monthly values of $t''$ are given, to be used in obtaining the argument in the first table, as proposed in § 35. When $t$ is observed at a time of day which does not give a mean temperature, a value of $t$ which does not differ much from the mean must be used, as already explained. Of course this leaves some uncertainty with regard to the proper value of $t$ to be used generally, but this cannot be avoided, since it is impossible to take into account, in all special cases, the abnormal variations of $\frac{1}{2}(t''+t)$ from the true temperature of the air column.

As an example of the application of the preceding tables, let us suppose that we have observed on the 1st of May at St. Bernard, at a time of day which gives the mean temperature of the day, or nearly, the value of $B=573^{mm}.5$ and $t=0^\circ.3$. From ($d$) we get, in this case, $\Delta B=573.5-560=13^{mm}.5$; and from Table III, $t''=12^\circ.5$. Hence $t''+t=12^\circ.5+0^\circ.3=12^\circ.8$. We therefore have

| | mm. |
|---|---|
| Table I, argument $12^\circ.8$, | 720. 1 |
| Table II, argument $13^{mm}.5$, | 17. 7 |
| Table III, argument May 1, | 0. 3 |
| | $B''=738.1$ |

If the time of the maximum of the correction in Table III coincides with that of the greatest temperature of the year, the correction might be included in Table I without sensible error. For St. Bernard the times of these maxima do not differ very much, but in many places, as Summit in California, the difference is nearly two months, so that in such cases the correction of Table III cannot be regarded as a function simply of the temperature.

## HYPSOMETRICAL TABLES.

### TABLE I.

*Containing log* 60521.5 $[1+.001017\ (t''+t-64^\circ)]$: *Argument*, $(t''+t)$.

| $t''+t$ | Log. | $t''+t$ | Log. | $t''+t$ | Log. | $t''+t$ | Log. | $t''\ \ t$ | Log. | $t''+t$ | Log. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ° | | ° | | ° | | ° | | ° | | ° | |
| 0 | 4. 75270 | 30 | 4. 76665 | 60 | 4. 78014 | 90 | 4. 79324 | 120 | 4. 80596 | 150 | 4. 81832 |
| 1 | 4. 75317 | 31 | 4. 76711 | 61 | 4. 78059 | 91 | 4. 79367 | 121 | 4. 80638 | 151 | 4. 81873 |
| 2 | 4. 75364 | 32 | 4. 76756 | 62 | 4. 78103 | 92 | 4. 79410 | 122 | 4. 80680 | 152 | 4. 81913 |
| 3 | 4. 75411 | 33 | 4. 76802 | 63 | 4. 78147 | 93 | 4. 79453 | 123 | 4. 80722 | 153 | 4. 81954 |
| 4 | 4. 75458 | 34 | 4. 76847 | 64 | 4. 78191 | 94 | 4. 79496 | 124 | 4. 80763 | 154 | 4. 81994 |
| 5 | 4. 75505 | 35 | 4. 76893 | 65 | 4. 78235 | 95 | 4. 79539 | 125 | 4. 80805 | 155 | 4. 82035 |
| 6 | 4. 75552 | 36 | 4. 76938 | 66 | 4. 78279 | 96 | 4. 79582 | 126 | 4. 80846 | 156 | 4. 82075 |
| 7 | 4. 75599 | 37 | 4. 76984 | 67 | 4. 78323 | 97 | 4. 79625 | 127 | 4. 80888 | 157 | 4. 82116 |
| 8 | 4. 75646 | 38 | 4. 77029 | 68 | 4. 78367 | 98 | 4. 79668 | 128 | 4. 80930 | 158 | 4. 82156 |
| 9 | 4. 75693 | 39 | 4. 77174 | 69 | 4. 78411 | 99 | 4. 79711 | 129 | 4. 89972 | 159 | 4. 82197 |
| 10 | 4. 75739 | 40 | 4. 77119 | 70 | 4. 78455 | 100 | 4. 79753 | 130 | 4. 81013 | 160 | 4. 82237 |
| 11 | 4. 75786 | 41 | 4. 77164 | 71 | 4. 78499 | 101 | 4. 79796 | 131 | 4. 81054 | 161 | 4. 82277 |
| 12 | 4. 75833 | 42 | 4. 77209 | 72 | 4. 78543 | 102 | 4. 79838 | 132 | 4. 81095 | 162 | 4. 82317 |
| 13 | 4. 75880 | 43 | 4. 77254 | 73 | 4. 78587 | 103 | 4. 79881 | 133 | 4. 81137 | 163 | 4. 82357 |
| 14 | 4. 75926 | 44 | 4. 77299 | 74 | 4. 78630 | 104 | 4. 79923 | 134 | 4. 81178 | 164 | 4. 82397 |
| 15 | 4. 75973 | 45 | 4. 77344 | 75 | 4. 78674 | 105 | 4. 79966 | 135 | 4. 81219 | 165 | 4. 82437 |
| 16 | 4. 76019 | 46 | 4. 77389 | 76 | 4. 78717 | 106 | 4. 80008 | 136 | 4. 81260 | 166 | 4. 82477 |
| 17 | 4. 76066 | 47 | 4. 77434 | 77 | 4. 78761 | 107 | 4. 80050 | 137 | 4. 81301 | 167 | 4. 82517 |
| 18 | 4. 76112 | 48 | 4. 77479 | 78 | 4. 78804 | 108 | 4. 80092 | 138 | 4. 81342 | 168 | 4. 82557 |
| 19 | 4. 76159 | 49 | 4. 77524 | 79 | 4. 78848 | 109 | 4. 80135 | 139 | 4. 81383 | 169 | 4. 82597 |
| 20 | 4. 76205 | 50 | 4. 77569 | 80 | 4. 78892 | 110 | 4. 80177 | 140 | 4. 81424 | 170 | 4. 82637 |
| 21 | 4. 76251 | 51 | 4. 77614 | 81 | 4. 78936 | 111 | 4. 80219 | 141 | 4. 81465 | 171 | 4. 82677 |
| 22 | 4. 76297 | 52 | 4. 77658 | 82 | 4. 78979 | 112 | 4. 80261 | 142 | 4. 81506 | 172 | 4. 82717 |
| 23 | 4. 76343 | 53 | 4. 77703 | 83 | 4. 79022 | 113 | 4. 80303 | 143 | 4. 81547 | 173 | 4. 82757 |
| 24 | 4. 76389 | 54 | 4. 77748 | 84 | 4. 79065 | 114 | 4. 80345 | 144 | 4. 81588 | 174 | 4. 82796 |
| 25 | 4. 76435 | 55 | 4. 77793 | 85 | 4. 79109 | 115 | 4. 80387 | 145 | 4. 81629 | 175 | 4. 82836 |
| 26 | 4. 76481 | 56 | 4. 77837 | 86 | 4. 79152 | 116 | 4. 80429 | 146 | 4. 81669 | 176 | 4. 82875 |
| 27 | 4. 76527 | 57 | 4. 77882 | 87 | 4. 79195 | 117 | 4. 80471 | 147 | 4. 80710 | 177 | 4. 82915 |
| 28 | 4. 76573 | 58 | 4. 77926 | 88 | 4. 79238 | 118 | 4. 80513 | 148 | 4. 81751 | 178 | 4. 82955 |
| 29 | 4. 76619 | 59 | 4. 77970 | 89 | 4. 79281 | 119 | 4. 80555 | 149 | 4. 81792 | 179 | 4. 82995 |
| 30 | 4. 76665 | 60 | 4. 78014 | 90 | 4. 79324 | 120 | 4. 80596 | 150 | 4. 81832 | 180 | 4. 83034 |

MULTIPLES OF THE DIFFERENCES.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 47 | 46 | 45 | 44 | 43 | 42 | 41 | 40 | 39 | 1 |
| 2 | 94 | 92 | 90 | 88 | 86 | 84 | 82 | 80 | 78 | 2 |
| 3 | 141 | 138 | 135 | 132 | 129 | 126 | 123 | 120 | 117 | 3 |
| 4 | 188 | 184 | 180 | 176 | 172 | 168 | 164 | 160 | 156 | 4 |
| 5 | 235 | 230 | 225 | 220 | 215 | 210 | 205 | 200 | 195 | 5 |
| 6 | 282 | 276 | 270 | 264 | 258 | 252 | 246 | 240 | 234 | 6 |
| 7 | 329 | 322 | 315 | 308 | 301 | 294 | 287 | 280 | 273 | 7 |
| 8 | 376 | 368 | 360 | 352 | 344 | 336 | 328 | 320 | 312 | 8 |
| 9 | 423 | 414 | 405 | 396 | 387 | 378 | 369 | 360 | 351 | 9 |

## TABLE II.

*Containing log* $\left(1+0.189\,\frac{b_1}{\mathrm{B}}\right)$ *in units of the fifth decimal place: Arguments,* B *and* $b_1$.

| B | $b_1$ in inches. | | | | | | | | | | | | | | | | | | | | B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .05 | .10 | .15 | .20 | .25 | .30 | .35 | .40 | .45 | .50 | .55 | .60 | .65 | .70 | .75 | .80 | .85 | .90 | .95 | 1.00 | |
| *In.* | | | | | | | | | | | | | | | | | | | | | *In.* |
| 11 | 36 | 73 | 109 | 146 | 183 | 220 | 257 | 296 | 338 | 372 | 408 | 445 | 481 | 518 | 555 | 595 | 631 | 669 | 705 | 741 | 11 |
| 12 | 34 | 68 | 102 | 136 | 170 | 204 | 238 | 273 | 307 | 341 | 374 | 408 | 442 | 476 | 510 | 544 | 578 | 612 | 646 | 678 | 12 |
| 13 | 32 | 64 | 95 | 126 | 158 | 189 | 221 | 252 | 283 | 314 | 345 | 376 | 408 | 439 | 471 | 502 | 533 | 564 | 596 | 626 | 13 |
| 14 | 30 | 59 | 88 | 117 | 147 | 176 | 205 | 234 | 263 | 292 | 321 | 350 | 379 | 408 | 437 | 466 | 495 | 524 | 553 | 582 | 14 |
| 15 | 28 | 55 | 82 | 109 | 137 | 164 | 191 | 218 | 246 | 273 | 300 | 327 | 354 | 381 | 408 | 435 | 463 | 490 | 517 | 544 | 15 |
| 16 | 26 | 51 | 77 | 102 | 128 | 153 | 179 | 205 | 231 | 256 | 282 | 307 | 333 | 358 | 383 | 408 | 434 | 459 | 485 | 510 | 16 |
| 17 | 24 | 48 | 72 | 96 | 121 | 145 | 169 | 193 | 217 | 241 | 265 | 289 | 313 | 337 | 361 | 384 | 408 | 432 | 456 | 480 | 17 |
| 18 | 23 | 46 | 69 | 91 | 114 | 137 | 160 | 182 | 205 | 227 | 250 | 273 | 296 | 318 | 341 | 363 | 386 | 408 | 431 | 454 | 18 |
| 19 | 21 | 43 | 65 | 86 | 108 | 129 | 151 | 172 | 194 | 215 | 237 | 258 | 280 | 301 | 323 | 344 | 366 | 387 | 409 | 430 | 19 |
| 20 | 20 | 41 | 61 | 82 | 102 | 123 | 143 | 164 | 184 | 205 | 225 | 246 | 266 | 286 | 307 | 327 | 348 | 368 | 388 | 408 | 20 |
| 21 | 19 | 39 | 58 | 78 | 97 | 117 | 136 | 156 | 175 | 195 | 214 | 234 | 253 | 273 | 292 | 312 | 331 | 350 | 369 | 389 | 21 |
| 22 | 18 | 37 | 56 | 75 | 94 | 112 | 131 | 149 | 168 | 186 | 205 | 223 | 242 | 260 | 279 | 297 | 316 | 334 | 353 | 371 | 22 |
| 23 | 18 | 36 | 54 | 71 | 89 | 107 | 125 | 143 | 161 | 178 | 196 | 214 | 232 | 249 | 267 | 285 | 303 | 320 | 338 | 355 | 23 |
| 24 | 17 | 34 | 51 | 68 | 85 | 103 | 120 | 137 | 154 | 171 | 188 | 205 | 222 | 239 | 256 | 273 | 290 | 307 | 324 | 341 | 24 |
| 25 | 17 | 33 | 50 | 66 | 82 | 98 | 115 | 131 | 148 | 164 | 181 | 197 | 213 | 229 | 246 | 261 | 278 | 294 | 311 | 328 | 25 |
| 26 | 16 | 32 | 48 | 63 | 79 | 95 | 111 | 126 | 142 | 158 | 174 | 189 | 205 | 220 | 236 | 252 | 268 | 283 | 299 | 315 | 26 |
| 27 | 15 | 30 | 46 | 61 | 76 | 91 | 106 | 121 | 137 | 152 | 167 | 182 | 197 | 212 | 227 | 242 | 258 | 273 | 288 | 303 | 27 |
| 28 | 15 | 29 | 44 | 59 | 74 | 88 | 103 | 117 | 132 | 146 | 161 | 176 | 191 | 205 | 220 | 234 | 249 | 263 | 278 | 292 | 28 |
| 29 | 14 | 28 | 42 | 56 | 71 | 85 | 99 | 113 | 127 | 141 | 155 | 169 | 184 | 198 | 212 | 226 | 240 | 254 | 268 | 282 | 29 |
| 30 | 14 | 27 | 41 | 55 | 69 | 82 | 96 | 109 | 123 | 137 | 151 | 164 | 178 | 191 | 205 | 218 | 232 | 245 | 259 | 273 | 30 |
| 31 | 13 | 26 | 40 | 53 | 66 | 79 | 93 | 106 | 119 | 132 | 145 | 158 | 172 | 185 | 198 | 211 | 225 | 238 | 251 | 264 | 31 |

NOTE.—When B and $b_1$ are given in millimeters multiply both by .04 or any other number that will bring them within the range of the arguments in the table.

## TABLE III.

*Containing log* $[1-.000084\,(t-t_1)]$ *: Argument,* $(t-t_1)$.

| $t-t_1$ | Comp. of log. | $t-t_1$ | Comp. of log. |
|---|---|---|---|
| ° F. | | ° F. | |
| 1 | −0.00004 | 16 | −0.00059 |
| 2 | 7 | 17 | 62 |
| 3 | 11 | 18 | 66 |
| 4 | 14 | 19 | 69 |
| 5 | 18 | 20 | 73 |
| 6 | 22 | 21 | 77 |
| 7 | 25 | 22 | 80 |
| 8 | 29 | 23 | 84 |
| 9 | 33 | 24 | 88 |
| 10 | 37 | 25 | 92 |
| 11 | 41 | 26 | 96 |
| 12 | 44 | 27 | 99 |
| 13 | 48 | 28 | 103 |
| 14 | 51 | 29 | 106 |
| 15 | −0.00055 | 30 | −0.00110 |

NOTE.—When $t_1$ is less than 32° F., deduct $\frac{1}{8}$ from the logarithm.

## TABLE IV.

*To be used in place of Tables II and III where no hygrometric observations are made.*

| $t'+t$ | Log. |
|---|---|
| ° F. | |
| 0 | 0.00030 |
| 10 | 37 |
| 20 | 45 |
| 30 | 53 |
| 40 | 62 |
| 50 | 73 |
| 60 | 88 |
| 70 | 110 |
| 80 | 138 |
| 90 | 175 |
| 100 | 215 |
| 110 | 256 |
| 120 | 297 |
| 130 | 338 |
| 140 | 379 |
| 150 | 420 |
| 160 | 460 |
| 170 | 501 |
| 180 | 0.00542 |

## TABLE V.

*Containing log* $\left(1+\frac{2h'}{r}\right)$: *Argument,* $h'$.

| $h'$ | Log. | $h'$ |
|---|---|---|
| *Feet.* | | *Meters.* |
| 100 | 0.00000 | 30 |
| 200 | 1 | 61 |
| 300 | 1 | 91 |
| 400 | 2 | 122 |
| 500 | 2 | 152 |
| 600 | 2 | 183 |
| 700 | 3 | 213 |
| 800 | 3 | 244 |
| 900 | 4 | 274 |
| 1,000 | 4 | 305 |
| 2,000 | 8 | 610 |
| 3,000 | 12 | 914 |
| 4,000 | 16 | 1,219 |
| 5,000 | 21 | 1,524 |
| 6,000 | 25 | 1,829 |
| 7,000 | 29 | 2,134 |
| 8,000 | 33 | 2,438 |
| 9,000 | 37 | 2,743 |
| 10,000 | 0.00041 | 3,048 |

## TABLE VI.

*Containing log* $\left(1+\frac{\mathrm{H}}{r}\right)$: *Argument, log* H.

| Log H. | Log. |
|---|---|
| 2.5 | 0.00001 |
| 3.0 | 2 |
| 3.1 | 3 |
| 3.2 | 3 |
| 3.3 | 4 |
| 3.4 | 5 |
| 3.5 | 7 |
| 3.6 | 8 |
| 3.7 | 10 |
| 3.8 | 13 |
| 3.9 | 17 |
| 4.0 | 21 |
| 4.1 | 26 |
| 4.2 | 33 |
| 4.3 | 0.00041 |

## TABLE VII.

*Containing log* (1+.002606 *cos* 2λ): *Argument*, λ.

| λ + | Log. | λ − | λ + | Log. | λ − |
|---|---|---|---|---|---|
| ° | | ° | ° | | ° |
| 0 | 0.00113 | 90 | 23 | 0.00079 | 67 |
| 1 | 113 | 89 | 24 | 76 | 66 |
| 2 | 113 | 88 | 25 | 73 | 65 |
| 3 | 113 | 87 | 26 | 70 | 64 |
| 4 | 113 | 86 | 27 | 67 | 63 |
| 5 | 112 | 85 | 28 | 63 | 62 |
| 6 | 112 | 84 | 29 | 60 | 61 |
| 7 | 111 | 83 | 30 | 57 | 60 |
| 8 | 110 | 82 | 31 | 54 | 59 |
| 9 | 108 | 81 | 32 | 50 | 58 |
| 10 | 107 | 80 | 33 | 46 | 57 |
| 11 | 105 | 79 | 34 | 43 | 56 |
| 12 | 104 | 78 | 35 | 39 | 55 |
| 13 | 102 | 77 | 36 | 35 | 54 |
| 14 | 101 | 76 | 37 | 31 | 53 |
| 15 | 99 | 75 | 38 | 28 | 52 |
| 16 | 97 | 74 | 39 | 24 | 51 |
| 17 | 94 | 73 | 40 | 20 | 50 |
| 18 | 92 | 72 | 41 | 16 | 49 |
| 19 | 89 | 71 | 42 | 12 | 48 |
| 20 | 87 | 70 | 43 | 8 | 47 |
| 21 | 84 | 69 | 44 | 4 | 46 |
| 22 | 0.00082 | 68 | 45 | 0.00000 | 45 |

## TABLE VIII.

*Containing log* [1−.0000895 (τ′−τ)]: *Argument*, (τ′−τ).

| τ′−τ | Comp. of log. | τ′−τ | Comp. of log. |
|---|---|---|---|
| ° | | ° | |
| 1 | −0.00004 | 21 | −0.00082 |
| 2 | 8 | 22 | 85 |
| 3 | 12 | 23 | 89 |
| 4 | 16 | 24 | 93 |
| 5 | 19 | 25 | 97 |
| 6 | 23 | 26 | 101 |
| 7 | 27 | 27 | 105 |
| 8 | 31 | 28 | 109 |
| 9 | 35 | 29 | 113 |
| 10 | 39 | 30 | 116 |
| 11 | 43 | 31 | 120 |
| 12 | 47 | 32 | 124 |
| 13 | 51 | 33 | 128 |
| 14 | 54 | 34 | 132 |
| 15 | 58 | 35 | 136 |
| 16 | 62 | 36 | 140 |
| 17 | 66 | 37 | 144 |
| 18 | 70 | 38 | 147 |
| 19 | 74 | 39 | 151 |
| 20 | −0.00078 | 40 | −0.00155 |

## TABLE IX.

*Containing the tension of aqueous vapor in saturated air, f, according to Regnault, expressed in inches of mercury, with t in degrees Fahrenheit as an argument.*

| *t* | Tension. | *t* | Tension. | *t* | Tension. | *t* | Tension. |
|---|---|---|---|---|---|---|---|
| ° | *Inches.* | ° | *Inches.* | ° | *Inches.* | ° | *Inches.* |
| 0 | 0.043 | 25 | 0.135 | 50 | 0.361 | 75 | 0.868 |
| 1 | 0.045 | 26 | 0.141 | 51 | 0.374 | 76 | 0.897 |
| 2 | 0.048 | 27 | 0.147 | 52 | 0.388 | 77 | 0.927 |
| 3 | 0.050 | 28 | 0.153 | 53 | 0.403 | 78 | 0.958 |
| 4 | 0.052 | 29 | 0.160 | 54 | 0.418 | 79 | 0.990 |
| 5 | 0.054 | 30 | 0.167 | 55 | 0.433 | 80 | 1.023 |
| 6 | 0.057 | 31 | 0.174 | 56 | 0.449 | 81 | 1.057 |
| 7 | 0.060 | 32 | 0.181 | 57 | 0.465 | 82 | 1.092 |
| 8 | 0.062 | 33 | 0.188 | 58 | 0.482 | 83 | 1.128 |
| 9 | 0.065 | 34 | 0.196 | 59 | 0.500 | 84 | 1.165 |
| 10 | 0.068 | 35 | 0.204 | 60 | 0.518 | 85 | 1.203 |
| 11 | 0.072 | 36 | 0.212 | 61 | 0.536 | 86 | 1.242 |
| 12 | 0.075 | 37 | 0.220 | 62 | 0.556 | 87 | 1.283 |
| 13 | 0.078 | 38 | 0.229 | 63 | 0.576 | 88 | 1.332 |
| 14 | 0.082 | 39 | 0.238 | 64 | 0.596 | 89 | 1.366 |
| 15 | 0.086 | 40 | 0.248 | 65 | 0.617 | 90 | 1.410 |
| 16 | 0.090 | 41 | 0.257 | 66 | 0.639 | 91 | 1.455 |
| 17 | 0.094 | 42 | 0.267 | 67 | 0.662 | 92 | 1.501 |
| 18 | 0.098 | 43 | 0.277 | 68 | 0.685 | 93 | 1.548 |
| 19 | 0.103 | 44 | 0.288 | 69 | 0.708 | 94 | 1.597 |
| 20 | 0.108 | 45 | 0.299 | 70 | 0.733 | 95 | 1.647 |
| 21 | 0.113 | 46 | 0.311 | 71 | 0.758 | 96 | 1.698 |
| 22 | 0.118 | 47 | 0.323 | 72 | 0.784 | 97 | 1.751 |
| 23 | 0.123 | 48 | 0.335 | 73 | 0.811 | 98 | 1.805 |
| 24 | 0.129 | 49 | 0.348 | 74 | 0.839 | 99 | 1.861 |

## TABLE X.

*Containing the tension of aqueous vapor in saturated air, f, expressed in millimeters of mercury, with t in degrees Centigrade as an argument.*

| *t* | Tension. | *t* | Tension. | *t* | Tension. | *t* | Tension. |
|---|---|---|---|---|---|---|---|
| ° | *mm.* | ° | *mm.* | ° | *mm.* | ° | *mm.* |
| −18 | 1.08 | − 4 | 3.39 | +10 | 9.17 | +24 | 22.18 |
| 17 | 1.17 | 3 | 3.66 | 11 | 9.79 | 25 | 23.55 |
| 16 | 1.27 | 2 | 3.96 | 12 | 10.46 | 26 | 24.99 |
| 15 | 1.38 | − 1 | 4.27 | 13 | 11.16 | 27 | 26.51 |
| 14 | 1.50 | 0 | 4.60 | 14 | 11.91 | 28 | 28.10 |
| 13 | 1.63 | + 1 | 4.94 | 15 | 12.70 | 29 | 29.78 |
| 12 | 1.77 | 2 | 5.30 | 16 | 13.54 | 30 | 31.55 |
| 11 | 1.92 | 3 | 5.69 | 17 | 14.42 | 31 | 33.40 |
| 10 | 2.08 | 4 | 6.10 | 18 | 15.36 | 32 | 35.36 |
| 9 | 2.26 | 5 | 6.53 | 19 | 16 35 | 33 | 37.41 |
| 8 | 2.46 | 6 | 7.00 | 20 | 17.39 | 34 | 39.56 |
| 7 | 2.67 | 7 | 7.49 | 21 | 18.50 | 35 | 41.83 |
| 6 | 2.89 | 8 | 8.02 | 22 | 19.66 | 36 | 44.23 |
| − 5 | 3.13 | + 9 | 8.57 | +23 | 20.89 | +37 | 46.77 |

## TABLE XI.

*Containing* $A=60521.5\,(1+.001017\times 36^{\circ})\,\log\frac{30}{B}$: *Argument, B.*

| B | A | Diff. for .01 | B | A | Diff. for .01 | B | A | Diff. for .01 | B | A | Diff. for .01 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *Inches.* | *Feet.* | *Feet.* | *Inches.* | *Feet.* | *Feet.* | *Inches.* | *Feet.* | *Feet.* | *Inches.* | *Feet.* | *Feet.* |
| 11.0 | 27,336 | −24.6 | 16.0 | 17,127 | −16.9 | 21.0 | 9,718 | −12.9 | 26.0 | 3,899 | −10.5 |
| 11.1 | 27,090 | 24.4 | 16.1 | 16,958 | 16.9 | 21.1 | 9,589 | 12.9 | 26.1 | 3,794 | 10.4 |
| 11.2 | 26,846 | 24.2 | 16.2 | 16,789 | 16.8 | 21.2 | 9,460 | 12.8 | 26.2 | 3,690 | 10 4 |
| 11.3 | 26,604 | 24.0 | 16.3 | 16,621 | 16.7 | 21.3 | 9,332 | 12.8 | 26.3 | 3,586 | 10.3 |
| 11.4 | 26,364 | 23.8 | 16.4 | 16,454 | 16.6 | 21.4 | 9,204 | 12.7 | 26.4 | 3,483 | 10.3 |
| 11.5 | 26,126 | 23.6 | 16.5 | 16,288 | 16.4 | 21.5 | 9,077 | 12.6 | 26.5 | 3,380 | 10.3 |
| 11.6 | 25,890 | 23.4 | 16 6 | 16,124 | 16.3 | 21.6 | 8,951 | 12.6 | 26.6 | 3,277 | 10.2 |
| 11.7 | 25,656 | 23.2 | 16.7 | 15,961 | 16.3 | 21.7 | 8,825 | 12.5 | 26.7 | 3,175 | 10.2 |
| 11.8 | 25,424 | 23.0 | 16.8 | 15,798 | 16.2 | 21.8 | 8,700 | 12.5 | 26.8 | 3,073 | 10.1 |
| 11.9 | 25,194 | 22.8 | 16.9 | 15,636 | 16.0 | 21.9 | 8,575 | 12.4 | 26.9 | 2,972 | 10.1 |
| 12.0 | 24,966 | 22.6 | 17.0 | 15,476 | 16.0 | 22.0 | 8,451 | 12.4 | 27.0 | 2,871 | 10.1 |
| 12.1 | 24,740 | 22.4 | 17.1 | 15,316 | 15.9 | 22.1 | 8,327 | 12.3 | 27.1 | 2,770 | 10 0 |
| 12.2 | 24,516 | 22.2 | 17.2 | 15,157 | 15.8 | 22.2 | 8,204 | 12.2 | 27.2 | 2,670 | 10.0 |
| 12.3 | 24,294 | 22.1 | 17.3 | 14,999 | 15.7 | 22.3 | 8,082 | 12.2 | 27.3 | 2,570 | 10.0 |
| 12.4 | 24,073 | 21.9 | 17.4 | 14,842 | 15.6 | 22.4 | 7,960 | 12.2 | 27.4 | 2,470 | 9.9 |
| 12.5 | 23,854 | 21.7 | 17.5 | 14,686 | 15.5 | 22.5 | 7,838 | 12.1 | 27.5 | 2,371 | 9.9 |
| 12.6 | 23,637 | 21.6 | 17.6 | 14,531 | 15.4 | 22.6 | 7,717 | 12.0 | 27.6 | 2,272 | 9.9 |
| 12.7 | 23,421 | 21.4 | 17.7 | 14,377 | 15.4 | 22.7 | 7,597 | 12.0 | 27.7 | 2,173 | 9.8 |
| 12.8 | 23,207 | 21.2 | 17.8 | 14,223 | 15.3 | 22.8 | 7,477 | 11.9 | 27.8 | 2,075 | 9.8 |
| 12.9 | 22,995 | 21.0 | 17.9 | 14,070 | 15.2 | 22.9 | 7,358 | 11.9 | 27.9 | 1,977 | 9.7 |
| 13.0 | 22,785 | 20.9 | 18.0 | 13,918 | 15.1 | 23.0 | 7,239 | 11.8 | 28.0 | 1,880 | 9.7 |
| 13.1 | 22,576 | 20.8 | 18.1 | 13,767 | 15.0 | 23.1 | 7,121 | 11.7 | 28.1 | 1,783 | 9.7 |
| 13.2 | 22,368 | 20.6 | 18.2 | 13,617 | 14.9 | 23.2 | 7,004 | 11.7 | 28.2 | 1,686 | 9.7 |
| 13.3 | 22,162 | 20.4 | 18.3 | 13,468 | 14.9 | 23.3 | 6,887 | 11.7 | 28.3 | 1,589 | 9.6 |
| 13.4 | 21,958 | 20.1 | 18.4 | 13,319 | 14.7 | 23.4 | 6,770 | 11.6 | 28.4 | 1,493 | 9.6 |
| 13.5 | 21,757 | 20.0 | 18.5 | 13,172 | 14.7 | 23.5 | 6,654 | 11.6 | 28.5 | 1,397 | 9.5 |
| 13.6 | 21,557 | 19.9 | 18.6 | 13,025 | 14.6 | 23.6 | 6,538 | 11.5 | 28.6 | 1,302 | 9.5 |
| 13.7 | 21,358 | 19.8 | 18.7 | 12,879 | 14.6 | 23.7 | 6,423 | 11.5 | 28.7 | 1,207 | 9.5 |
| 13.8 | 21,160 | 19.8 | 18.8 | 12,733 | 14.4 | 23.8 | 6,308 | 11.4 | 28.8 | 1,112 | 9.4 |
| 13.9 | 20,962 | 19.7 | 18.9 | 12,589 | 14.4 | 23.9 | 6,194 | 11.4 | 28.9 | 1,018 | 9.4 |
| 14.0 | 20,765 | 19.5 | 19.0 | 12,445 | 14.3 | 24.0 | 6,080 | 11.3 | 29.0 | 924 | 9.4 |
| 14.1 | 20,570 | 19.3 | 19.1 | 12,302 | 14.2 | 24.1 | 5,967 | 11.3 | 29.1 | 830 | 9.4 |
| 14.2 | 20,377 | 19.1 | 19.2 | 12,160 | 14.2 | 24.2 | 5,854 | 11.3 | 29.2 | 736 | 9.3 |
| 14.3 | 20,186 | 18.9 | 19.3 | 12,018 | 14.1 | 24.3 | 5,741 | 11.2 | 29.3 | 643 | 9.3 |
| 14.4 | 19,997 | 18.8 | 19.4 | 11,877 | 14.0 | 24.4 | 5,629 | 11.1 | 29.4 | 550 | 9.2 |
| 14.5 | 19,809 | 18.6 | 19.5 | 11,737 | 13.9 | 24.5 | 5,518 | 11.1 | 29.5 | 458 | 9.2 |
| 14.6 | 19,623 | 18.6 | 19.6 | 11,598 | 13.9 | 24.6 | 5,407 | 11.1 | 29.6 | 366 | 9.2 |
| 14.7 | 19,437 | 18.5 | 19.7 | 11,459 | 13.8 | 24.7 | 5,296 | 11.0 | 29.7 | 274 | 9.2 |
| 14.8 | 19,252 | 18.4 | 19.8 | 11,321 | 13.7 | 24.8 | 5,186 | 10.9 | 29 8 | 182 | 9.1 |
| 14.9 | 19,068 | 18.2 | 19.9 | 11,184 | 13.7 | 24.9 | 5,077 | 10.9 | 29.9 | 91 | 9.1 |
| 15.0 | 18,886 | 18.1 | 20.0 | 11,047 | 13.6 | 25.0 | 4,968 | 10.9 | 30.0 | 00 | 9.1 |
| 15.1 | 18,705 | 18.0 | 20.1 | 10,911 | 13.5 | 25.1 | 4,859 | 10.8 | 30.1 | −91 | 9.0 |
| 15.2 | 18,525 | 17.9 | 20.2 | 10,776 | 13.4 | 25.2 | 4,751 | 10.8 | 30.2 | 181 | 9.0 |
| 15.3 | 18,346 | 17.8 | 20.3 | 10,642 | 13.4 | 25.3 | 4,643 | 10.8 | 30.3 | 271 | 9.0 |
| 15.4 | 18,168 | 17.6 | 20.4 | 10,508 | 13.3 | 25.4 | 4,535 | 10.7 | 30.4 | 361 | 9.0 |
| 15.5 | 17,992 | 17.5 | 20.5 | 10,375 | 13.3 | 25.5 | 4,428 | 10.7 | 30.5 | 451 | 8.9 |
| 15.6 | 17,817 | 17.4 | 20.6 | 10,242 | 13.2 | 25.6 | 4,321 | 10.6 | 30.6 | 540 | 8.9 |
| 15.7 | 17,643 | 17.3 | 20.7 | 10,110 | 13.1 | 25.7 | 4,215 | 10.6 | 30.7 | 629 | 8.8 |
| 15.8 | 17,470 | 17.2 | 20.8 | 9,979 | 13.1 | 25.8 | 4,109 | 10.5 | 30.8 | 717 | 8.8 |
| 15.9 | 17,298 | −17.1 | 20.9 | 9,848 | −13.0 | 25.9 | 4,004 | −10.5 | 30.9 | 805 | −8.8 |
| 16.0 | 17,127 |  | 21.0 | 9,718 |  | 26.0 | 3,899 |  | 31.0 | −893 |  |

## TABLE XII.

*Giving the tensions of aqueous vapor, G, by Glaisher's tables, and the differences, G—R, between Glaisher's tables and Regnault's formula: Arguments, t and t—$t_1$.*

| t—$t_1$ | $t=10°$ | | $t=20°$ | | $t=30°$ | | $t=40°$ | | $t=50°$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | G | G—R | G | G—R | G | G—R | G | G—R | G | G—R |
| ° | *Inches.* | | *Inches.* | | *Inches.* | | *Inches.* | | *Inches.* | |
| 0 | .068 | .000 | .108 | .000 | .167 | .000 | .247 | .000 | .361 | .000 |
| 1 | .046 | —.008 | .073 | —.019 | .140 | —.009 | .226 | +.001 | .334 | —.001 |
| 2 | .031 | .009 | .051 | .025 | .116 | .014 | .207 | .004 | .309 | .000 |
| 3 | .021 | —.006 | .034 | .026 | .096 | .017 | .189 | .008 | .286 | +.003 |
| 4 | .012 | .000 | .024 | .020 | .080 | .015 | .172 | .012 | .205 | .007 |
| 5 | ........ | ........ | .016 | .013 | .066 | .012 | .156 | .017 | .245 | .011 |
| 6 | ........ | ........ | .010 | —.004 | .055 | —.005 | .142 | .024 | .226 | .017 |
| 7 | ........ | ........ | .006 | ........ | .045 | +.002 | .129 | .032 | .208 | .022 |
| 8 | ........ | ........ | .003 | ........ | .037 | .010 | .117 | .040 | .191 | .029 |
| 9 | ........ | ........ | ........ | ........ | .031 | +.021 | .106 | .049 | .176 | .037 |
| 10 | ........ | ........ | ........ | ........ | .025 | ........ | .096 | .058 | .162 | .045 |
| 11 | ........ | ........ | ........ | ........ | .02 | ........ | .087 | .067 | .149 | .055 |
| 12 | ........ | ........ | ........ | ........ | .016 | ........ | .078 | +.075 | .136 | .064 |
| 13 | ........ | ........ | ........ | ........ | .013 | ........ | .068 | ........ | .124 | .073 |
| 14 | ........ | ........ | ........ | ........ | .010 | ........ | .058 | ........ | .113 | .084 |
| 15 | ........ | ........ | ........ | ........ | .007 | ........ | .048 | ........ | .103 | +.096 |

| t—$t_1$ | $t=60°$ | | $t=70°$ | | $t=80°$ | | $t$ 90° | | $t=100°$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | G | G—R | G | G—R | G | G—R | G | G—R | G | G—R |
| ° | *Inches.* | | *Inches.* | | *Inches.* | | *Inches.* | | *Inches.* | |
| 0 | .518 | .000 | .733 | .000 | 1.023 | .000 | 1.411 | .000 | 1.918 | .000 |
| 1 | .485 | —.002 | .691 | —.004 | 0.968 | —.009 | 1.342 | —.010 | 1.828 | —.019 |
| 2 | .453 | .003 | .651 | .007 | .916 | .015 | 1.276 | .020 | 1.742 | .035 |
| 3 | .422 | .004 | .613 | .009 | .867 | .020 | 1.212 | .030 | 1.660 | .049 |
| 4 | .395 | —.001 | .576 | .010 | .820 | .023 | 1.151 | .036 | 1.582 | .061 |
| 5 | .369 | +.002 | .541 | .009 | .775 | .025 | 1.092 | .043 | 1.508 | .070 |
| 6 | .344 | .006 | .508 | .008 | .732 | .026 | 1.036 | .047 | 1.437 | .077 |
| 7 | .321 | .011 | .476 | .006 | .690 | .027 | 0.982 | .051 | 1.368 | .084 |
| 8 | .299 | .017 | .446 | —.003 | .650 | .027 | .930 | .053 | 1.301 | .090 |
| 9 | .278 | .023 | .418 | +.002 | .613 | .024 | .880 | .055 | 1.237 | .094 |
| 10 | .259 | .030 | .392 | .007 | .578 | .020 | .833 | .054 | 1.175 | .098 |
| 11 | .241 | .038 | .368 | .014 | .545 | .016 | .788 | .053 | 1.116 | .099 |
| 12 | .224 | .047 | .345 | .022 | .513 | .011 | .745 | .051 | 1.060 | .099 |
| 13 | .208 | .056 | .323 | .030 | .483 | —.004 | .704 | .048 | 1.006 | .099 |
| 14 | .193 | .066 | .302 | .039 | .455 | +.003 | .665 | .043 | 0.955 | .096 |
| 15 | .179 | .077 | .283 | .049 | .429 | .012 | .629 | .036 | .907 | .091 |
| 16 | .166 | .088 | .265 | .059 | .404 | .022 | .595 | .028 | .861 | .086 |
| 17 | .154 | .099 | .247 | .069 | .380 | .031 | .562 | .020 | .818 | .079 |
| 18 | .142 | .111 | .230 | .080 | .357 | .041 | .531 | .011 | .777 | .070 |
| 19 | .131 | .122 | .214 | .091 | .335 | .052 | .501 | —.001 | .738 | .061 |
| 20 | .120 | ........ | .199 | .102 | .315 | .064 | .473 | +.009 | .700 | .052 |
| 21 | ........ | ........ | .185 | .114 | .296 | .076 | .446 | .020 | .663 | .042 |
| 22 | ........ | ........ | .172 | .127 | .278 | .088 | .421 | .032 | .628 | .032 |
| 23 | ........ | ........ | .159 | .139 | .261 | .101 | .397 | .044 | .594 | .022 |
| 24 | ........ | ........ | .147 | ........ | .245 | .115 | .374 | .056 | .562 | —.010 |
| 25 | ........ | ........ | ........ | ........ | .229 | .127 | .351 | .068 | .532 | +.002 |
| 26 | ........ | ........ | ........ | ........ | .214 | .141 | .329 | .081 | .503 | .015 |
| 27 | ........ | ........ | ........ | ........ | .201 | .155 | .308 | .094 | .476 | .029 |
| 28 | ........ | ........ | ........ | ........ | .188 | .168 | .290 | .108 | .449 | .043 |
| 29 | ........ | ........ | ........ | ........ | .176 | ........ | .273 | .121 | .424 | .038 |
| 30 | ........ | ........ | ........ | ........ | .165 | ........ | .258 | .134 | .401 | +.035 |

## TABLE XIII.

### *Height of a column of air corresponding to a tenth of an inch in the barometer.*

| Bar. | Temperature. | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 20° | 25° | 30° | 35° | 40° | 45° | 50° | 55° | 60° | 65° | 70° | 75° | 80° | 85° | 90° |
| *Inches.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* | *Feet.* |
| 22.0 | 116.72 | 117.97 | 119.23 | 120.50 | 121.80 | 123.12 | 124.45 | 125.80 | 127.14 | 128.49 | 129.83 | 131.18 | 132.53 | 133.88 | 135.24 |
| .2 | 115.67 | 116.91 | 118.15 | 119.42 | 120.70 | 122.02 | 123.34 | 124.67 | 125.99 | 127.33 | 128.66 | 130.00 | 131.34 | 132.68 | 134.02 |
| .4 | 114.64 | 115.86 | 117.10 | 118.35 | 119.63 | 120.92 | 122.23 | 123.55 | 124.87 | 126.19 | 127.51 | 128.84 | 130.16 | 131.49 | 132.82 |
| .6 | 113.62 | 114.84 | 116.06 | 117.30 | 118.57 | 119.85 | 121.15 | 122.46 | 123.76 | 125.07 | 126.38 | 127.69 | 129.01 | 130.33 | 131.64 |
| .8 | 112.63 | 113.83 | 115.04 | 116.28 | 117.53 | 118.80 | 120.08 | 121.39 | 122.68 | 123.98 | 125.28 | 126.57 | 127.88 | 129.19 | 130.50 |
| 23.0 | 111.65 | 112.84 | 114.04 | 115.27 | 116.50 | 117.77 | 119.04 | 120.33 | 121.61 | 122.90 | 124.19 | 125.47 | 126.77 | 128.06 | 129.36 |
| .2 | 110.68 | 111.87 | 113.06 | 114.27 | 115.50 | 116.76 | 118.02 | 119.29 | 120.56 | 121.84 | 123.12 | 124.40 | 125.68 | 126.96 | 128.25 |
| .4 | 109.74 | 110.91 | 112.09 | 113.29 | 114.51 | 115.76 | 117.01 | 118.27 | 119.53 | 120.80 | 122.06 | 123.33 | 124.60 | 125.87 | 127.15 |
| .6 | 108.81 | 109.97 | 111.15 | 112.33 | 113.54 | 114.78 | 116.02 | 117.27 | 118.52 | 119.77 | 121.03 | 122.29 | 123.55 | 124.81 | 126.07 |
| .8 | 107.89 | 109.05 | 110.21 | 111.38 | 112.59 | 113.81 | 115.05 | 116.29 | 117.52 | 118.77 | 120.01 | 121.26 | 122.51 | 123.76 | 125.01 |
| 24.0 | 107.00 | 108.14 | 109.29 | 110.46 | 111.65 | 112.87 | 114.09 | 115.32 | 116.55 | 117.78 | 119.01 | 120.25 | 121.49 | 122.73 | 123.97 |
| .2 | 106.11 | 107.25 | 108.39 | 109.55 | 110.73 | 111.93 | 113.15 | 114.37 | 115.58 | 116.81 | 118.03 | 119.25 | 120.49 | 121.72 | 122.95 |
| .4 | 105.24 | 106.37 | 107.50 | 108.65 | 109.82 | 111.02 | 112.22 | 113.43 | 114.63 | 115.85 | 117.06 | 118.28 | 119.50 | 120.72 | 121.94 |
| .6 | 104.39 | 105.50 | 106.63 | 107.77 | 108.93 | 110.11 | 111.31 | 112.51 | 113.70 | 114.91 | 116.11 | 117.32 | 118.53 | 119.74 | 120.95 |
| .8 | 103.55 | 104.65 | 105.77 | 106.90 | 108 05 | 109.23 | 110.41 | 111.60 | 112.79 | 113.98 | 115.18 | 116.37 | 117.57 | 118.77 | 119.97 |
| 25.0 | 102.72 | 103.81 | 104.92 | 106.04 | 107.19 | 108.35 | 109.53 | 110.71 | 111.88 | 113.07 | 114.25 | 115.44 | 116.63 | 117.82 | 119.01 |
| .2 | 101.90 | 102.99 | 104.09 | 105.20 | 106.34 | 107.49 | 108.66 | 109.83 | 111.00 | 112.17 | 113.35 | 114.52 | 115.71 | 116.89 | 118.07 |
| .4 | 101.10 | 102.18 | 103.27 | 104.38 | 105.50 | 106.64 | 107.80 | 108.96 | 110.12 | 111.29 | 112.45 | 113.62 | 114.79 | 115.97 | 117.14 |
| .6 | 100.31 | 101.38 | 102.46 | 103.56 | 104.67 | 105.81 | 106.96 | 108.11 | 109.26 | 110.42 | 111.58 | 112.74 | 113.90 | 115.06 | 116.22 |
| .8 | 99.53 | 100.60 | 101.67 | 102.76 | 103.86 | 104.99 | 106.13 | 107.27 | 108.41 | 109.56 | 110.71 | 111.86 | 113.01 | 114.17 | 115.32 |
| 26.0 | 98.77 | 99.82 | 100.89 | 101.97 | 103.07 | 104.19 | 105.31 | 106.45 | 107.58 | 108.72 | 109.86 | 111.00 | 112.14 | 113.29 | 114.44 |
| .2 | 98.01 | 99.06 | 100.12 | 101.19 | 102.28 | 103.39 | 104.51 | 105.64 | 106.76 | 107.89 | 109.02 | 110.15 | 111.29 | 112.42 | 113.56 |
| .4 | 97.27 | 98.31 | 99.36 | 100.42 | 101.50 | 102.61 | 103.72 | 104.84 | 105.95 | 107.07 | 108.19 | 109.32 | 110.45 | 111.57 | 112.70 |
| .6 | 96.54 | 97.57 | 98.61 | 99.67 | 100.74 | 101.83 | 102.94 | 104.05 | 105.16 | 116.27 | 107.38 | 108.50 | 109.61 | 110.73 | 111.86 |
| .8 | 95.82 | 96.84 | 97.87 | 98.92 | 99.99 | 101.08 | 102.17 | 103.27 | 104.37 | 105.48 | 106.58 | 107.69 | 108.80 | 109.91 | 111.02 |
| 27.0 | 95.11 | 96.12 | 97.15 | 98.19 | 99.25 | 100.33 | 101.41 | 102.51 | 103.60 | 104.70 | 105 79 | 106.89 | 107.99 | 109.09 | 110.20 |
| .2 | 94.41 | 95.42 | 96.43 | 97.47 | 98.52 | 99.60 | 100.67 | 101.75 | 102.84 | 103.92 | 105.01 | 106.10 | 107.20 | 108.29 | 109.39 |
| .4 | 93.72 | 94.72 | 95.73 | 96.76 | 97.80 | 98.86 | 99.93 | 101.01 | 102.09 | 103.17 | 104.25 | 105.33 | 106.42 | 107.50 | 108.59 |
| .6 | 93.04 | 94.03 | 95.04 | 96.06 | 97.09 | 98.14 | 99.21 | 100.28 | 101.35 | 102.42 | 103.49 | 104.57 | 105.64 | 106.72 | 107.80 |
| .8 | 92.37 | 93.36 | 94.35 | 95.37 | 96.39 | 97.44 | 98.50 | 99.56 | 100.62 | 101.68 | 102.75 | 103.81 | 104.88 | 105.95 | 107.03 |
| 28.0 | 91.71 | 92.69 | 93.68 | 94.68 | 95.70 | 96.74 | 97.79 | 98.84 | 99.90 | 100.95 | 102.01 | 103.07 | 104.13 | 105.20 | 106.26 |
| .2 | 91.06 | 92.03 | 93.02 | 94.01 | 95.02 | 96.06 | 97.10 | 98.14 | 99.19 | 100.24 | 101.29 | 102.34 | 103.40 | 104.45 | 105.51 |
| .4 | 90.42 | 91.39 | 92.36 | 93.35 | 94.35 | 95.38 | 96.41 | 97.45 | 98.49 | 99.53 | 100.58 | 101.62 | 102.67 | 103.71 | 104.77 |
| .6 | 89.79 | 90.75 | 91.71 | 92.70 | 93.69 | 94.71 | 95.74 | 96.77 | 97.80 | 98.84 | 99.87 | 100.91 | 101.95 | 102.99 | 104.03 |
| .8 | 89.17 | 90.12 | 91.08 | 92.06 | 93.05 | 94.06 | 95.08 | 96.10 | 97.12 | 98.15 | 99.18 | 100.21 | 101.24 | 102.28 | 103.31 |
| 29.0 | 88.55 | 89.49 | 90.45 | 91.42 | 92.40 | 93.41 | 94.42 | 95.44 | 96.45 | 97.47 | 98.49 | 99.52 | 100.54 | 101.57 | 102.60 |
| .2 | 87.94 | 88.88 | 89.83 | 90.79 | 91.77 | 92.77 | 93.77 | 94.78 | 95.79 | 96.81 | 97.82 | 98.84 | 99.86 | 100.88 | 101.90 |
| .4 | 87.35 | 88.28 | 89.22 | 90.18 | 91.15 | 92.14 | 93.14 | 94.14 | 95.14 | 96.15 | 97.15 | 98.16 | 99.18 | 100.19 | 101.20 |
| .6 | 86.76 | 87.68 | 88.62 | 89.57 | 90.53 | 91.51 | 92.51 | 93.50 | 94.50 | 95.50 | 96.50 | 97.50 | 98.51 | 99.51 | 100.52 |
| .8 | 86.17 | 87.09 | 88.02 | 88.96 | 89.92 | 90.90 | 91.89 | 92.87 | 93.86 | 94.86 | 95.85 | 96.85 | 97.84 | 98.84 | 99.84 |
| 30.0 | 85.60 | 86.51 | 87.43 | 88.37 | 89.32 | 90.29 | 91.27 | 92.26 | 93.24 | 94.22 | 95.21 | 96.20 | 97.19 | 98.18 | 99.18 |
| .2 | 85.03 | 85.94 | 86.85 | 87.79 | 88.73 | 89.69 | 90.66 | 91.65 | 92.63 | 93.60 | 94.58 | 95.56 | 96.55 | 97.53 | 98.52 |
| .4 | 84.47 | 85.38 | 86.28 | 87.22 | 88.15 | 89.10 | 90.06 | 91.05 | 92.03 | 92.99 | 93.96 | 94.93 | 95.91 | 96.88 | 97.87 |
| .6 | 83.92 | 84.83 | 85.73 | 86.66 | 87.58 | 88.52 | 89.47 | 90.46 | 91.43 | 92.38 | 93.35 | 94.31 | 95.28 | 96.25 | 97.22 |
| .8 | 83.38 | 84.28 | 85.18 | 86.10 | 87.01 | 87.95 | 88.90 | 89.07 | 90.83 | 91.78 | 92.75 | 93.70 | 94.66 | 95.62 | 96.58 |

## TABLE XIV.

*Correction for capillary depression.*

| Diameter of tube. | Height of meniscus in inches. | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | .005 | .010 | .015 | .020 | .025 | .030 | .035 | .040 | .045 | .050 | .055 | .060 | .065 | .070 |
| *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* | *Inch.* |
| 0.20 | .009 | .018 | .027 | .035 | .043 | .050 | .056 | .061 | .066 | .070 | ....... | ....... | ....... | ....... |
| .22 | 8 | 15 | 22 | 29 | 35 | 41 | 46 | 51 | 55 | 59 | .063 | ....... | ....... | ....... |
| .24 | 6 | 12 | 18 | 24 | 29 | 34 | 39 | 43 | 46 | 49 | 52 | .055 | ....... | ....... |
| .26 | 5 | 10 | 15 | 20 | 24 | 28 | 33 | 36 | 39 | 42 | 44 | 46 | ....... | ....... |
| .28 | 4 | 8 | 12 | 16 | 20 | 24 | 27 | 30 | 32 | 35 | 37 | 39 | ....... | ....... |
| .30 | 4 | 7 | 10 | 13 | 17 | 20 | 23 | 25 | 27 | 30 | 32 | 33 | .035 | .036 |
| .32 | 3 | 6 | 9 | 11 | 14 | 17 | 20 | 22 | 24 | 26 | 28 | 29 | 31 | 32 |
| .34 | 3 | 5 | 8 | 9 | 11 | 14 | 17 | 19 | 20 | 22 | 24 | 25 | 26 | 28 |
| .36 | 3 | 5 | 7 | 8 | 10 | 12 | 14 | 16 | 17 | 18 | 20 | 21 | 22 | 23 |
| .38 | 2 | 4 | 6 | 7 | 9 | 11 | 12 | 14 | 15 | 16 | 18 | 19 | 20 | 20 |
| .40 | 2 | 3 | 5 | 6 | 8 | 10 | 11 | 12 | 14 | 15 | 16 | 17 | 18 | 18 |
| .42 | 2 | 3 | 4 | 5 | 6 | 8 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 16 |
| .44 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 12 | 13 | 14 | 14 |
| .46 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 10 | 11 | 12 | 12 |
| .48 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 10 |
| .50 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | 8 | 8 | 9 |
| .52 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 7 | 7 | 8 |
| .54 | 1 | 1 | 2 | 3 | 4 | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 7 | 7 |
| 0.56 | .001 | .001 | .002 | .002 | .003 | .003 | .004 | .004 | .005 | .005 | .006 | .006 | .006 | .006 |

[END OF THIRD PART.]

## ERRATA IN PART II.

The following errors have been detected and communicated by Dr. A. Sprung, of Hamburg, Germany:

§ 2, *eq.* (1), for $2(n \cos \psi + \nu)$, read $(2n \cos \psi + \nu)$. This makes the small term depending upon $e$, in § 11, *eq.* (12) vanish.

§ 3, *eq.* (8), for $\cos \varphi$, read $n \cos \varphi$.

§ 91, *eq.* ($a$), for $2uv$, read $uv$.

§ 96, fifth line from bottom of page, for $gdh$, read $gD_8h$.

§ 100, *eq.* ($v$), supply first member $h_1$.

§ 100, *eq.* ($w$), for 1796, read 1996.

§ 102, table, for the numbers in the second column, read ..., 180, 275, 297, 302.

FIG.1

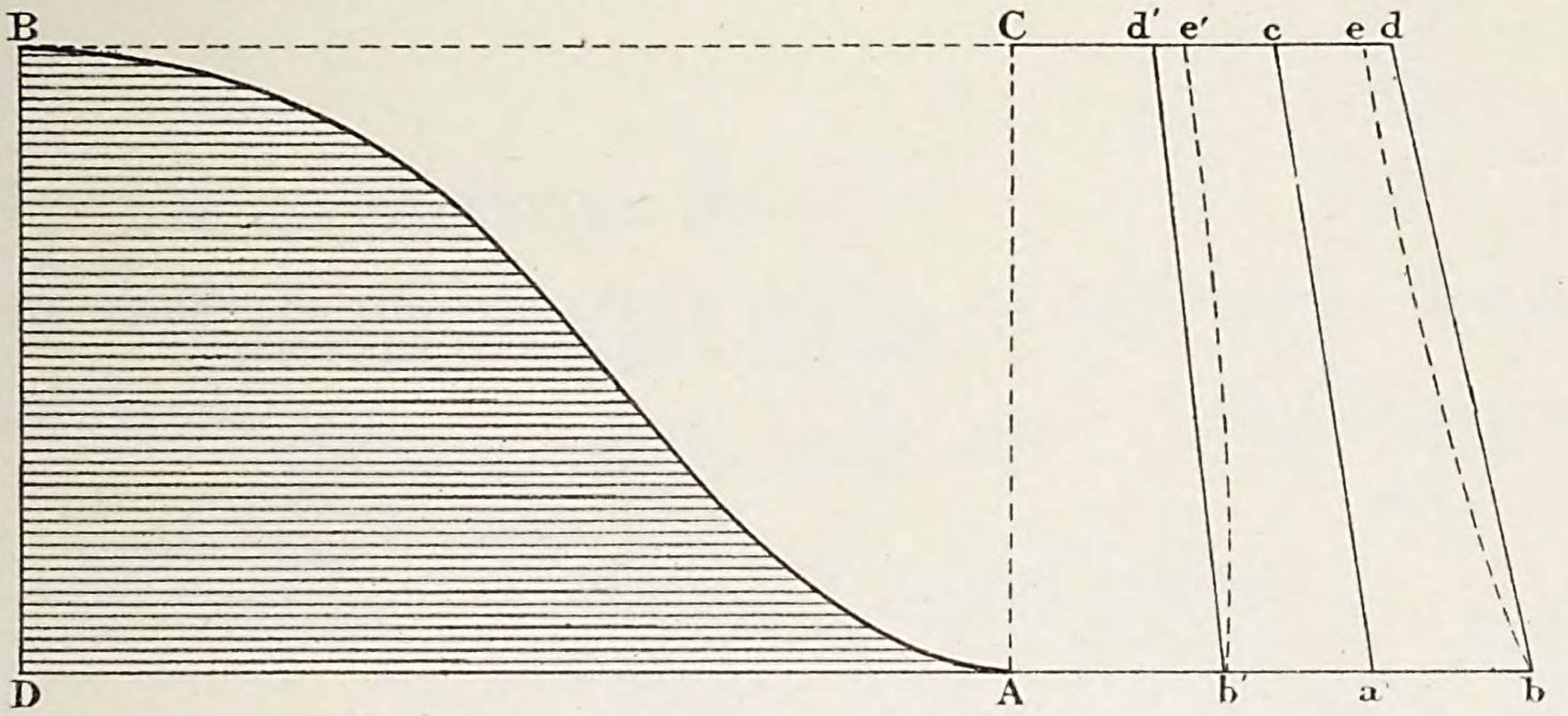


FIG.2

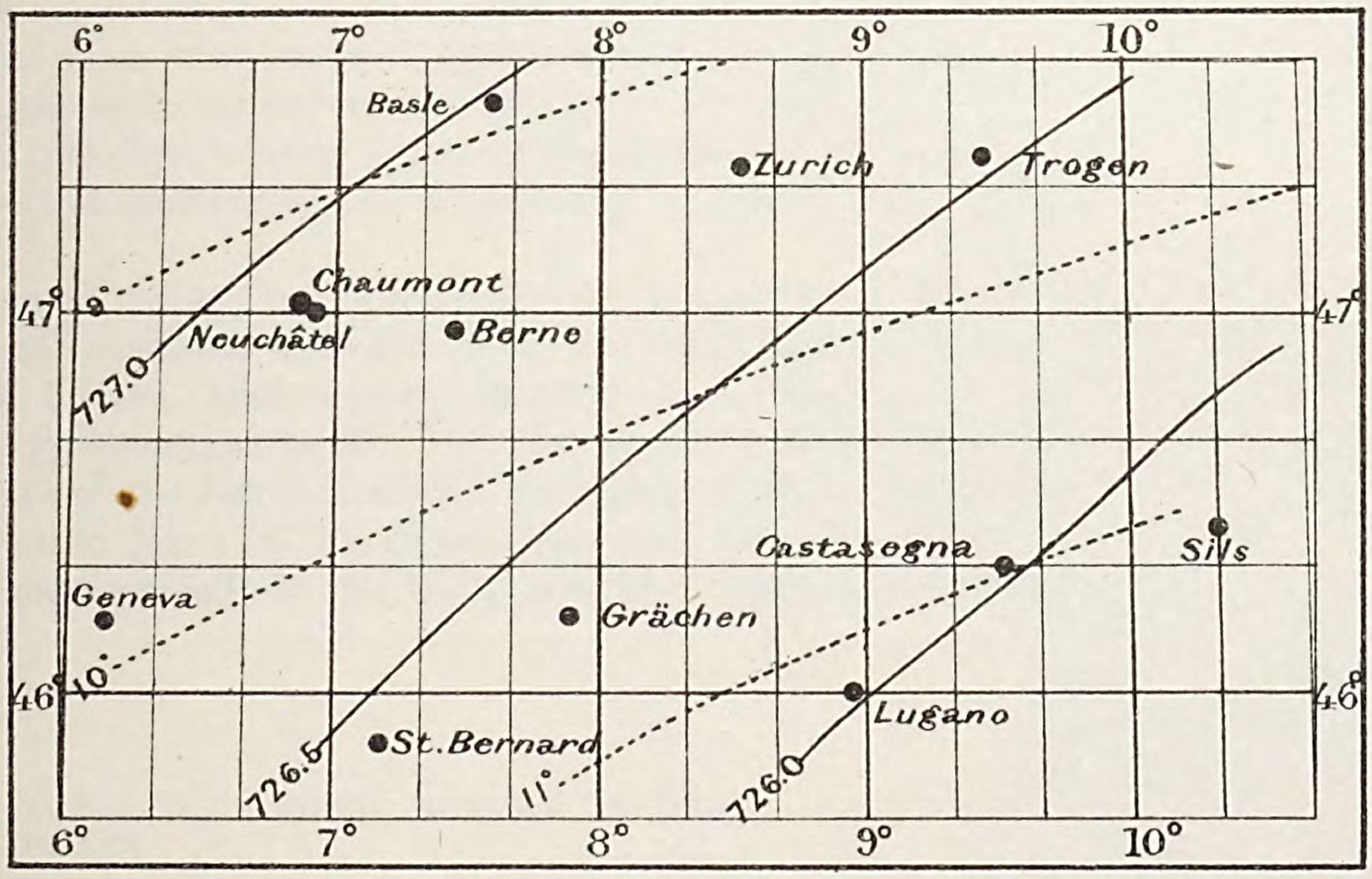
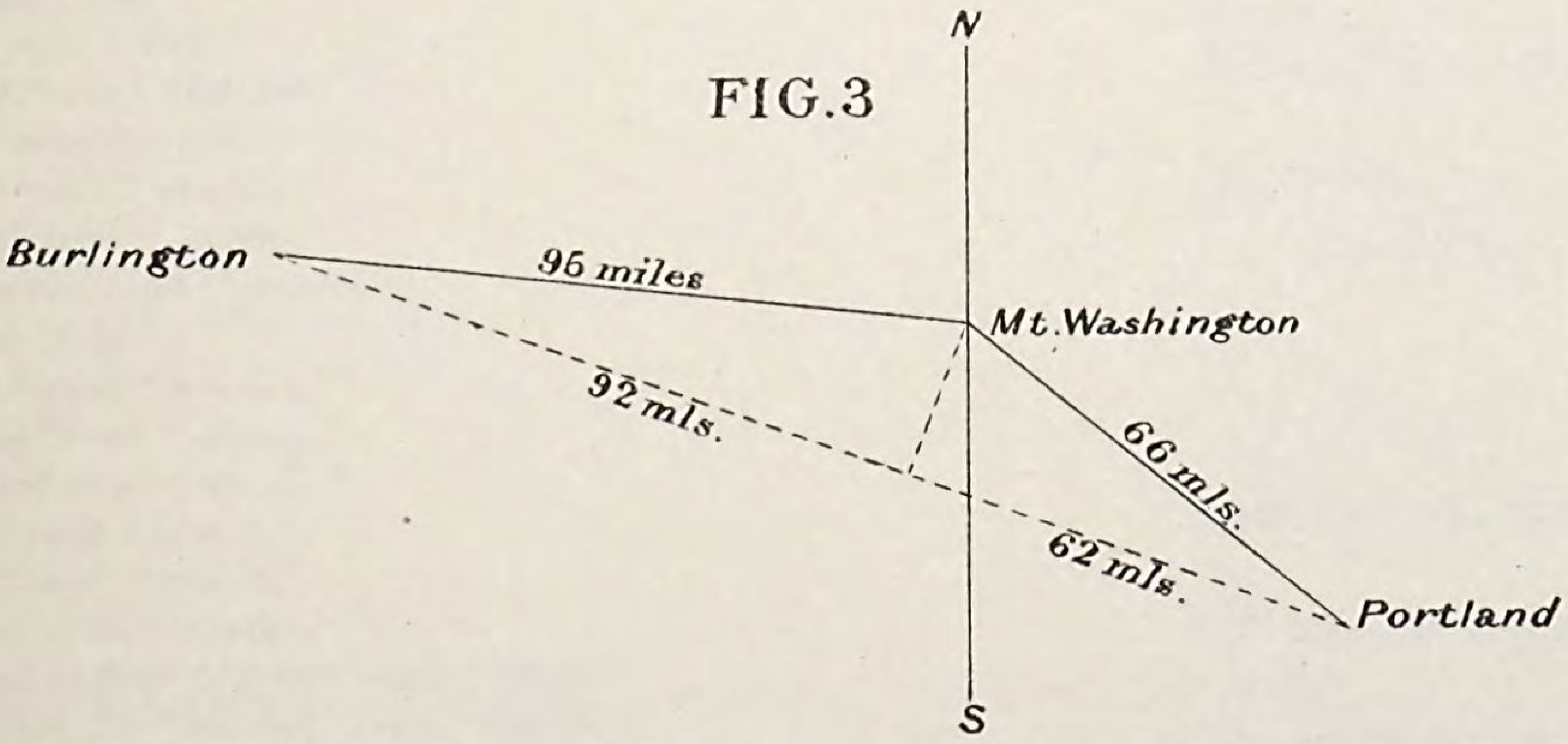


FIG.3



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# APPENDIX No. 11.

## REPORT ON THE OYSTER BEDS OF THE JAMES RIVER, VIRGINIA, AND OF TANGIER AND POCOMOKE SOUNDS, MARYLAND AND VIRGINIA.

By FRANCIS WINSLOW, Master U. S. Navy, Assistant Coast and Geodetic Survey, Commanding Schooner Palinurus.

### PREFACE.

In editing the following reports, it has been my endeavor, while preserving the original form and design, to omit such matters as would be of no interest to the public, but which were properly communicated to the Superintendent of the Survey. Of such a character I have considered the history of the work, in so much as it related to the difficulties encountered in its prosecution, and the various recommendations as to special matters connected with future operations. I have also considered that the same minuteness of description, either of methods or results, which was manifestly proper in a report to my superior, would be unnecessary in a paper intended for general circulation. I have, therefore, in some parts, condensed the reports considerably, though always with care that the reader should experience no difficulty in following the steps by which I reached any conclusion.

In the manuscript reports and in letters to the late Superintendent, I have frequently testified to the kindness and assistance rendered me by the inhabitants of Crisfield, Md., and of the shores of the sounds, and I wish to again express, in a more public manner, my appreciation of their efforts, and especially my indebtedness to Mr. T. S. Hodson, the collector of the port. My thanks are also due to the members of the Johns Hopkins Zoological School, to Prof. S. F. Baird, United States Fish Commissioner, to Mr. T. B. Ferguson, Maryland Fish Commissioner, to Mr. H. J. Rice, and Mr. W. H. Dall, and especially to Dr. W. K. Brooks for assistance rendered me.

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ANCIS WINSLOW,
*Lieutenant, U. S. N.*

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ERRATA TO APPENDIX No. 11—COAST AND GEODETIC SURVEY REPORT FOR 1881.

Page 273, line 43 from top, for "Moelius" read "Möbius."
Page 280, line 8 from top, for "up" read "rip."
Page 290, line 34 from top, for "Fog" read "Fox."
Page 293, line 44 from top, for "600,000" read "630,000."
Page 300, line 23 from top, for "light" read "bight."
Page 312, line 7 from top, for "welks" read "whelks."
Page 312, line 10 from top, for "welks" read "whelks."
Page 330, line 3 from top, for "successive" read "successful."
Page 331, line 2 from top, for "in" read "the."
Page 336, line 28 from top, for "welks" read "whelks."
Page 336, line 28 from top, for "*cinereus*" read "*cinerea.*"
Page 336, line 36 from top, for "*cinereus*" read "*cinerea.*"
Page 336, line 37 from top, for "welk" read "whelk."
Page 336, line 38 from top, for "welk" read "whelk."
Page 336, line 40 from top, for "welks" read "whelks."
Page 345, Appendix A, area Clump Point, for "382,000" read "382,500."
Page 345, Appendix A, area Horsey's Bar, for "202,000" read "202,500."
Page 345, Appendix A, area of Cow and Calf, for "292,000" read "292,500."
Page 345, Appendix A, area Cedar, for "337,000" read "337,500."
Pages 352 and 353, Appendix E, for "Monroe" read "Munroe," and for "analysis" read "analyses" wherever occurring.
Page 352, Appendix E, line 6, for "furnishes" read "furnish."
Page 352, Appendix E, insert at head of table "parts in 1,000,000 of water."

[For volume.]

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### PREFACE.

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As such success as has attended my labors in this field is largely due to the zealous and efficient co-operation of my brother officers and companions on board the Palinurus, I have felt it their due that their contributions to the results should be known. I have accordingly prefixed to each report the names of my assistants and have specified those portions of the work for which they are in a measure responsible.

I regret that it is not in my power to more adequately express my appreciation of the zeal and energy they displayed, the arduous nature of their labors in the field, and the good judgment they showed in the compilations assigned them in the office, and while it is difficult to make a distinction, I feel my indebtedness to Master H. H. Barroll, U. S. N., to be greater than to any other one connected with the investigation.

FRANCIS WINSLOW,
*Lieutenant, U. S. N.*

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### INSTRUCTIONS.

The instructions of the Superintendent, dated August 2, 1878, directed that the investigation of the oyster beds should include the following:

1. The determination of the positions and areas of the oyster beds of the Chesapeake and its adjacent waters and the depth of water over them both at high and low water.

2. The determination of the character of the beds; whether natural or artificial; whether the

oysters were spread all over a given area, or grew in clusters of large or small size, or were scattered singly or in small groups.

3. The determination of the temperatures of the surface and bottom water at each locality and the velocities of the currents.

4. The preservation of specimens of oysters of different ages, from each locality, and specimens of the bottom and bottom water.

5. The determination of the existence of any deposit of mud or other earthy or vegetable material and the determination of the character of the bottom beneath the oyster beds.

6. The determination of the source of the sediment if any was deposited and the means of directing it, if injurious, away from the beds. Also to determine whether ice ever rested on the beds and so destroyed them.

7. The determination of the density of the water, with special reference to the question of displacement of the salt water by the fresh water from adjacent streams and rivers.

The Superintendent also desired that the examination should, at first, be confined to a limited area and made exhaustive. Subsequently the investigation was to be extended as far as the means at the disposal of the Survey would permit.

The instructions were received on the 3d August, 1878. On the 7th of that month the vessel sailed from Baltimore, Md., to execute them, and the party remained actively in the field until the 15th October, when the season closed. As the investigation was novel in design and execution, and as the difficulties encountered by the party were mainly due to the absence of all experience and previous exertions in the same field, I have thought it best to preface the account of the results of our labors by a short description of the methods employed in making the several determinations required by my instructions.

## METHOD OF CONDUCTING THE INVESTIGATION.

The examination of the different beds was carried on in the following manner:

### 1.—Delineation of the beds.

The services of an oysterman of experience, and who was well acquainted with the localities of the different beds, was first obtained; the vessel was then anchored in such a position as to enable her use as one of the points for angling upon, and her position carefully fixed by sextant angles upon all points recognizable upon the chart. At the same time angles were taken upon any object that might be useful subsequently in fixing positions, either of the boats or schooner. By carrying forward our own points in that manner it was possible to dispense with signals, the erection of which would have occasioned much delay and the sacrifice of time and labor, to procure an unnecessary degree of accuracy. The boats then ran traverse lines, more or less open, over the adjacent beds, the size of the interior angle and the length of the line depending upon the supposed size and character of the bed; our general method was to work with the tide and endeavor to cross the lines as we returned over the ground. The "oyster pilot" was sent in one boat and one of the ship's company, who was an old oysterman, was sent in the other. They were provided with poles, which were marked to feet, and continually probed and examined the bottom as the boat passed over the line. The depth of water and character of the bottom were recorded as in ordinary hydrographic surveys. The position of the boat was frequently ascertained by sextant angles, but as the "points" were not always well defined, two angles were not considered sufficient, and angles on all prominent objects were taken. Occasionally, when in proximity to the schooner, mast-head angles and bearings were used for ascertaining the position of the boat, and in a few cases the bearing and distance of some well-defined point of land was estimated.

At intervals the boat was anchored, her position fixed, and specimens of oysters, bottom, and water obtained, and the temperature of the air, and surface and bottom water, observed; the character of the substratum of the bottom was also noted, and the set and velocity of the current recorded. The observations for ascertaining the character of the bottom beneath the surface and those for temperature were more frequently made than the others, and the current was measured only at such points as would give a fair idea of the general set of the flood and ebb tides; but whenever an oyster specimen was taken, all the observations, with the exception of those for strength and direction of current, were made. Only general instructions could be given as to the points on the beds where it was desirable to obtain specimens of any kind, or observations for temperature or character of bottom, and much was necessarily left to the discretion of the officer of the boat, not only with regard to those points but also as to the general delineation of the beds.

So far as it went the work was satisfactory, but there were three great drawbacks to the use of the boats, viz: The time and labor necessary to effect anything with them, the inability to use the pole with any accuracy in depths over three fathoms, and the failure of the pole to discover anything but the solid beds. We attempted to use with the boats a small and light dredge made especially for us, but found it impracticable, the largest boat, when under oars, fully manned, or when under sail in a stiff breeze, being unable to tow the dredge or even to move it; consequently the boats were useless for collecting any information, except over solid beds in less than three fathoms of water.

To define the limits of those beds lying in deeper water and of those not entirely solid, or where the oysters were scattered either in groups or singly, recourse was had to dredging with the schooner, using an ordinary oyster dredge of 36 inches width and with twelve teeth. This method was found to be so much more satisfactory in all respects, that all the boat work, whenever it was possible, was supplemented by dredging lines run by the schooner. Traverses were made as with the boats, and observations for ascertaining the character of the bottom, both of the surface and substrata, observations of temperature, and the selection of the various specimens, were carried on. The position of the vessel, however, was more frequently ascertained than had been customary in the boat work. The lowest possible rate of speed was maintained that was consistent with safe and ready manoeuvering (a matter of some difficulty), and the dredge put over at intervals varying from two to ten minutes, and depending upon the character and extent of the bed, depth of water, and ability of the crew to get the dredge in, it being at times necessary to heave the vessel to in order to recover it. The dredge was put over from the weather side, and, after having dragged a sufficient distance to insure its bringing up a specimen, should there be any oysters, was hauled in by hand. The presence of oysters on the bottom was readily detected by placing the hand on the dredging rope, the uneven, jumping motion of the dredge as it gathered the oysters and shells being distinctly perceptible. The dredge was usually on the bottom from thirty to forty-five seconds, which length of time was sufficient for our purpose and sometimes enough to fill the dredge, a catastrophe which was not desirable. Soundings were taken along the lines, and, with the character of the bottom, recorded.

The following form for keeping the record was used and found to be of great value:

RECORD.

[Date, September 5, 1878. Day-mark, S. Recorder, S. E. Stevens.]

| Time. | Depth. | Station. | Bottom. | Dredge. | Amount in dredge. | Ground log. | Right object. | Left object. |
|---|---|---|---|---|---|---|---|---|
| *h. m. sec.* | | | | | | | | |
| 7 10 20 | 15 feet. | 3 | Hard. .. | Over... | ⅓ full...... | 34 fms. | Clay Island Light-House ........ | Red trees. |
| 30 | .......... | .......... | .......... | Taking | 168 | ........ | Red trees ........................ | Tall trees. |
| 11 00 | .......... | ........ | .......... | Off bot. | oysters. | .......... | Tall trees ..... .................. | Solomon's Lump Light-House. |

| Angles. | Specimens. | | | Tide. | Temperatures. | | | Remarks on oysters. | General remarks. |
|---|---|---|---|---|---|---|---|---|---|
| | Oysters. | Bottom. | Water. | | Air. | Surface. | Bottom. | | |
| ° ′ | | | | | ° | ° | ° | | |
| 52 08 | 3 | 1 | 1 | ½ flood. | 59 | 68 | 68 | Large, single ..... .............. | Probed: 2 feet oysters, then hard. 100 sail dredging to southward. Wind, SW—3. |
| 68 23 | ........ | .......... | ........ | ........ | ........ | .......... | ........ | Young growth and clusters ...... | |
| 28 00 | ........ | .......... | ....... | ........ | ........ | .......... | .......... | Many young and drills; no sponge | |

The number of oysters in the dredge, the portion of the dredge filled, the character of the oysters, whether old or young, single or in clusters, large or small, the character of the parasites attached to the shells, the amount of grass, seaweed, and sponge in the dredge, the estimated number of young smaller than the marketable size, and other pertinent remarks, were noted after each haul. At intervals during the day the number of dredging vessels in sight was recorded for reference, and subsequently an attempt was made to collect data for the estimation of the number of oysters taken in a day by each sail. At each anchorage the current was measured.

From the results given by using the pole in the boats and the dredge in the schooner, the outlines of the beds have been traced on the chart, the lines defining their limits including nearly all stations when the number of oysters was greater than one-tenth to the square yard, and though in some portions of the beds, as shown on the charts, the number was less than one-tenth, yet other circumstances, such as the character of the bottom, the amount of shell brought up by the dredge, &c., have caused them to be included as part of the beds.

The limit of scattered oysters can only be considered as approximate, as the lines were drawn from information received from local oystermen and from such observations as we were enabled to make ourselves. As has been already stated, the boats were unable to ascertain the positions of any but the solid beds or large clusters, and the schooner not being able to work in less than 8 feet of water, our ability to determine the area covered by the scattered oysters was necessarily limited. As that area, and indeed that of the solid beds also, is variable, changing from year to year, the line inclosing the scattered oysters may be considered as accurate as it is necessary to have it.

## TIDES.

The mean rise and fall of the tides in the sounds is so slight (amounting to 2.3 feet in Tangier and 2.4 feet in Pocomoke), and generally the depth of water over the beds so great, that it was not considered necessary to establish tide gauges except in one case; such tidal corrections as have been applied to the soundings have been obtained from the Coast Survey Tide Tables. A comparison of the rise and fall of the tides, as given by those tables, with that given by a tide-staff erected at Clay Island Light-House, showed that during the months of October and November the greatest difference was nine-tenths of a foot. Owing to the vernal and autumnal gales the most considerable departure from the usual height of the tidal water occurs at those seasons, and it is therefore probable that one foot will represent the maximum error of the Coast Survey Tide Tables, and 3½ feet the maximum rise of the tide in either sound. Considering the great depth of water over the majority of the beds, it was concluded that the slight variation in those depths caused by the tides could have but little influence on the oysters, and consequently the correction of soundings except in depths less than three fathoms has been neglected.

## SPECIMENS.

The oyster specimens, 754 in number, were selected from large quantities brought up by the dredge and tongs, the endeavor being to take three specimens of different ages from each locality. One specimen of an adult oyster of two years' growth or more, one of from one to two years' growth, and one less than a year old, were usually selected. Shells, either old or new, and especially those having a large number of young clinging to them, were also occasionally preserved, and though a few specimens of oysters that had been transplanted were secured in order to show the effect of change of water, bottom, and depth, yet no examination of the planted beds was undertaken. In the selection of specimens we attempted to reserve such as would indicate the effect of different natural conditions. At the close of the day's work the oyster specimens were washed in salt water, opened carefully with a sharp-pointed, thin-bladed knife, and the upper valve detached from the muscle, and then replaced. A small wooden peg was then placed between the bills of the shell, the valves tied tightly together with twine, and the oyster wrapped in cotton cloth of a very open texture. The whole was placed in alcohol. The wooden peg kept the shell open sufficiently to allow the alcohol access to the body of the animal, and the cloth wrapper prevented the destruction or loss of anything of interest which might be attached to the shell. Six parts of alcohol to four of water were used, and to each specimen was attached a wooden label showing from whence the oyster came.

### BOTTOM AND WATER SPECIMENS.

The specimens of bottom were obtained from large amounts of sand, mud, and gravel, brought up by the dredge or tongs. When the bottom was hard, an ordinary bottom specimen cup screwed into a 25-pound lead was used, but over the solid beds, or where the bottom was of hard sand, it was very difficult to obtain anything, either with dredge, tongs, or lead.

The specimens of bottom water were secured by using the drop-water cylinders, which are fully described by Lieut. Frederick Collins, U. S. N., Assistant Coast and Geodetic Survey, in his report on the "Densities of the Waters of Chesapeake Bay and Tributaries," published by the Survey in the Report for 1877, Appendix No. 14. The cylinders worked as successfully as during the previous summer, and there can be no doubt that the water brought up by them was a specimen of that at the bottom. All the specimens were tested with a hydrometer, and the readings reduced to those at the standard temperature of 60° F.

### SUBSTRATUM OF BOTTOM.

The character of the bottom beneath the surface was roughly ascertained by means of an iron probe, 5 feet in length, attached to a long wooden staff. The probe was thrust as far as possible into the bottom, and the composition and character of the substratum estimated, the different constituents, whether sand, shell, mud, clay, or gravel, being easily recognized. Owing to the velocity of the currents, the speed of the vessel, and the difficulty of handling a long staff, but few determinations of the character of the substratum were made when the depth of water was greater than 3 fathoms.

### CURRENTS.

The currents were measured by a current meter, or by an ordinary chip log, though the latter was not used frequently. The position of the stations for measuring the current was left to the discretion of the officer of the boat, but a sufficient number have been occupied to show the set and strength of the main current, and the effect on them of the prevailing winds.

### NUMBER OF OYSTERS TO THE SQUARE YARD.

The number of oysters to the square yard was found by using a ground log in connection with the dredge. From the information derived from experienced oystermen, and from our own examination of those beds that had been dredged, I was of the opinion that a dredge, when of considerable size, and dragged slowly, usually collected everything met by it in its course. Considering that, at the suggestion of Mr. Rice, I used a small ground log to measure the distance traveled by the dredge. As that instrument was exactly one yard in width, it was concluded that it swept approximately clean one square yard for every linear yard it passed over. The ground log consisted of a small lead, a few ounces in weight, attached to a light line 1,000 feet long; between the lead and line was a length of copper wire of 20 feet; the line was marked every 5 fathoms and kept in a tub or on a reel ready for use; the lead was conical in shape to prevent its catching on shell clusters. When the dredge was thrown over the lead was dropped to the bottom and allowed to remain there, the line running out freely until the dredge was lifted off the bottom, when the line was stopped and the number of fathoms run off with the number of oysters in the dredge recorded. The dredge was not allowed to remain on the bottom long enough to be filled, consequently none of the oysters were lost from its inability to receive them.

Though the foregoing method was imperfect it was the best that could be devised under the circumstances, and a similar method was used by Moelius in ascertaining the number of oysters on the Schleswig-Holstein bed. From the very small number of oysters to the square yard, as shown by the method, from the small number of oysters it assigns to the beds, and from comparison of the latter number with the number known to have been taken off the beds during our stay in the sounds, it is evident that the "number to the square yard" given in the records of the work are useful for comparison only; for in almost all cases the number of oysters given to the square yard must be considered as far below the real number. For instance, the number of oysters on the beds in Tangier Sound, south of Jane's Island Light-House, was estimated from the data of the record given by the dredge and log to be 7,994,692, while from other observations I am positive that at least 2,000,000 oysters were taken from those beds in six days at the commencement of the oyster season. Such could hardly have been the case had there been but 8,000,000 oysters on the beds, and consequently we must regard the "number of oysters to the square yard," as shown by the method used, only valuable as establishing an initial number and standard by which the increase or decrease of oysters on the beds may be ascertained, and by which one bed or locality can be compared with another. Alone, the results of the dredge and log are valueless.

### TEMPERATURE OF THE WATER.

It was originally intended that the temperature of the bottom water should be obtained by means of thermometers attached to the "drop cylinders" used for obtaining the specimens of water from the bottom, and six of those cylinders were fitted at the office with mercurial thermometers, inclosed within the spindle upon which the cylinder moves, the bulb of the thermometer being a little above the center of the cylinder when closed on the lower disk, and the graduated stem being exposed above the top, thus allowing the temperature to be read within any limits that would probably occur.

Under the direction of the assistant in charge of the office, a series of experiments were made by Mr. H. W. Blair, in order to ascertain the correction to be applied to the thermometers when moved through strata of water of different temperatures, and from water of one temperature into the air at another. With tables of corrections derived from those experiments, and with care in using the apparatus, we hoped to arrive at results that would be very nearly correct, but I regret to say that upon the first occasion when the cylinders were tried the thermometers were shown to be useless.

The cylinder is closed upon the lower metal disk by means of a spiral brass spring, which also holds the cylinder down firmly, thus preventing the escape of the specimen. The spring acts with considerable force, and we found that invariably the shock of the closure of the cup was sufficient to break the mercurial column and prevent any reading of the thermometer. Attempts were made on board the vessel to remedy the evil by diminishing the strength of the spring, and by placing a rubber buffer on the lower disk, but we were unable to prevent leakage, and subsequently the same difficulty was experienced at the office.

Owing to the failure of the thermometers in the water cylinders, and the inability to obtain any apparatus, at so short a notice, in time to be available for the season's work, we were forced to use ordinary unprotected thermometers, furnished by the Coast Survey Office, with corrections established by experiments made previously and subsequently to the work of the party. The thermometers were fastened to a lead, lowered to the bottom, and kept there a sufficient time to acquire the temperature of the surrounding water. They were then hauled up as rapidly as possible and the temperature read; at the same time the temperatures of the air and surface water was noted.

Owing to the rapid change of reading when the thermometers were moved through strata of different temperature, the observations are only reliable when the temperatures of the air, surface, and bottom water were identical.

As the investigation extended over so short a period of time, and as the spawning season had closed before we arrived on the ground, the recorded temperatures are of little interest, and have been omitted in the following papers.

### NAMES AND AREAS.

In naming and describing the beds I have used the local names given them by the oystermen. The term "rock" is with them synonymous with "bed," as they regard only the solid portions of the area covered by the oysters. In the following pages the term "rock" indicates the solid, or approximately solid, portions of the bed. Areas are given in feet and miles. When the latter unit is used it is the nautical mile of 6,080 feet, and not the statute mile.

## REPORT OF THE INVESTIGATION CONDUCTED DURING THE SUMMER OF 1878.

My subordinates and assistants during the season were Master H. H. Barroll, U. S. N., and Mr. S. E. Stevens. Mr. Barroll tested the water specimens, 475 in number, and corrected the hydrometer readings for temperature; and compiled and arranged the record books and the various tables appended and referred to in the report. Mr. Stevens assisted in plotting the work, calculated the areas of the beds and of the bottom covered by scattered oysters, and developed the profiles of the bottom.

### OYSTER BEDS OF THE JAMES RIVER, VIRGINIA.

The examination of these beds was a very hurried one, and the delineation must be regarded as merely approximate, being the result of a hasty reconnaissance. On that account no attempt has been made to produce a chart similar to that of Tangier and Pocomoke Sounds, but the outlines of the beds, as shown by a few traverses run by the boats and as indicated by the local oystermen, have been sketched in roughly.

According to such information as it was possible for us to obtain, the beds do not extend above Deep Water Light, with the exception of a few small ones that are seldom fished on the account of the inferiority of the animals. We had not time to determine ourselves whether the information was correct, but I presume it to be so.

Below Deep Water Light the beds of any consequence are twelve in number, and of a total area (approximate) of 10.4 square miles. Taking them in order from Deep Water Light to Hampton Roads they are the Mulberry Point Bed, Point of Shoals Bed, Jail Island Bed, Blunt Point Bed, White Shoal Bed, Thomas's Point Bed, Kettle Hole Bed, Brown Shoal Bed, Bally Smash Bed, Naseway Shoal Bed, Cruiser's Bed, and the Nansemond Ridge Bed. The beds are "natural," and the following remarks apply to all.

*Currents.*—Nineteen observations were made of the currents, and established that, over the Mulberry Point, Jail Island, and Point of Shoals Beds, the general set of the flood is NW., with a maximum velocity of 0.5 mile per hour, and the general set of the ebb SE., with a maximum velocity of 1.7 miles per hour. These velocities were measured after or during moderate to stiff NW. breezes and spring tides, which conditions would increase the velocity of the ebb current considerably; it is probable that that velocity does not exceed one knot per hour under ordinary circumstances. The set both on flood and ebb is directly across the bed, but the main body of water follows the deep channel to the southward, the ebb striking the shore in Burwell's Bay, and at times washing a good deal of it away.

Over the Blunt Point, White Shoal, Thomas's Point, Kettle Hole, and Brown's Shoal Beds the current sets NW. and SE., with a maximum velocity of 0.8 mile per hour on the flood. The ebb on the first quarter showed a velocity of 0.3 mile per hour, and probably the maximum velocity is but little over one knot per hour, as the great body of water passes to the southward of the beds.

On the southern side of the river, over the Bally Smash, Naseway Shoal, Nansemond Ridge, and Cruiser's Beds, the general set of the currents is NW. and SE., except where the very shoal spots are met, when the current becomes variable in direction though not diminished in force. When the shoal ledge lies in the general direction of the river the effect does not appear to be so great, but where the shoal extends across the main current it is deflected from its usual course, and forms strong counter currents and eddies. Thus over the Bally Smash Bed the ebb was found to set to the SE., with a maximum velocity of 1.1 miles; over the Naseway Shoal on one side of the shoal ridge the set of the ebb was SW., with a velocity of 0.4 mile per hour; while on the other side of the ridge an observation made at about the same time showed a set of 0.2 mile NE. When clear of the obstructing shoals the current sets to the northward and westward on the flood, and to the southward and eastward on the ebb, with an average velocity of 0.5 mile per hour.

Over the Nansemond Ridge beds and inside of them the flood sets in towards Ragged Creek, and the ebb probably in the opposite direction.

In order to determine whether the salt water over the beds in the river, and especially over the Mulberry Point, Point of Shoals, and Jail Island Beds was displaced by the fresh water of the spring ebbs, specimens of water were obtained at every two fathoms of depth, on a section across the river just above Deep Water Light, at low water, spring tide. The density of the water at that point and time is shown in the following table:

*Section across James River.*

| Location. | Station. | Depth. | Tide. | Specific gravity. | Remarks. |
|---|---|---|---|---|---|
| | | *Feet.* | | | |
| Near Deep Water Light-House | A | Surface | Low water | 1.0083 | |
| | A | 6 | ....do | 1.0084 | Bottom, soft mud. |
| | B | Surface | ....do | 1.0088 | |
| | B | 12 | ....do | 1.0082 | |
| | B | 24 | ....do | 1.0088 | Bottom, soft mud. |
| | C | Surface | ....do | 1.0077 | |
| | C | 6 | ....do | 1.0078 | Bottom, soft mud. |

Comparing the specific gravity of the water obtained in the sections with that of two stations below Deep Water Light, which was obtained at nearly high water, a difference of density of 0.0037 is shown—1.0000 representing distilled water. So slight a change of density can hardly have any material effect upon the oysters, and, except during long-continued freshets, which occur sometimes during the spring, the animals in all probability do not suffer therefrom.

According to the oystermen, during the winter ice frequently grounds on the shoal spots on the Beds, but never remains there long, unless the weather is of unusual severity, the strength of the current and the variability of the climate being sufficient to remove the ice in a short space of time. As to the amount of damage done the oysters by the ice, opinions varied a good deal; the general impression was that, though the oysters were poorer in quality and flavor, the ice did not remain long enough to kill many of them. Only a few persons could be interrogated, and they were not very intelligent; but, in the absence of any opportunity to investigate the matter ourselves, their opinion is given.

All the beds in the James River are subject to the deposit of mud and vegetable matter brought down by the freshets that occur in the spring. The Mulberry Point, Point of Shoals, and Jail Island Beds, owing to their position, are particularly unfortunate in this respect. The set of the current being directly across these beds, they are the first to receive whatever is held by the water. From the character and appearance of the river, it is probable that a large amount of earthy matter is brought down by every ebb tide; but the velocity of the current is so great, and the shoal rises so abruptly between the Point of Shoals Light and Deep Water Light, forming a wall and barrier, that the principal part of the sediment seems to be carried into Burwell's Bay, where it has gradually covered and destroyed a large number of small beds. The spring freshets always cover the Mulberry Point, Point of Shoals, and Jail Island Beds, but not always for a sufficient time to very seriously damage the oysters, the current managing to sweep off the deposit in time to expose the cultch to the spat. Occasionally the damage is great; for instance, we were informed that during 1871 and 1872 there were a succession of heavy freshets, which destroyed the fishing for several years. In 1876, the mud having been washed away and the cultch exposed, a growth of young oysters was noticed in all the beds about and above Jail Island. In 1877 the oysters about Deep Water Light were good, and probably during the coming seasons (1878–'79), the catch on all the beds will be large, as at the time of our observations the oysters were numerous, with the young growth predominating. Apparently, then, it requires from three to five years for the beds to recover from the effects of heavy freshets, and as the oyster becomes marketable in about two years, from five to seven years must elapse from the date of the freshet before the beds can be profitably worked.

Happily, the other beds are affected to a much less extent, though about the shoals on the southern side of the river the oysters are gradually deteriorating, presumably from deposit of deleterious matter. The variability of the currents about these shoal places, and the fact that the depth of water about them is decreasing and the shoals increasing in size, appears to support the inference. On top of the Naseway Shoal, which is completely dry at low water, quantities of shells were found, and in its immediate neighborhood, especially to the northward and westward, the oysters were of a very poor quality, having deteriorated much of late years. In addition to the deposit by the James River, the Nansemond Ridge and beds off Pig Point receive a portion of the sediment brought down by the Nansemond River, but, other causes not operating, that deposit would not be sufficient to seriously injure the beds. Below Jail Island, on the northern side of the river, the beds are not so much affected by the deposit, and the oysters found on them are of a better quality than those on the opposite side of the channel.

Without incurring an expense not justified by the end sought, there is no practicable means of protecting the beds from this evil. Natural efforts appear to have sufficiently protected them in the past, and, if they are guarded in other respects, the loss on account of the deposit of matter brought down by the current, which is but occasional, will not interfere, to any great extent, with the industry.

*Mulberry Point Beds.*—These beds comprise an area (approximate) of 3,656,000 square yards. They lie to the southward and westward of Mulberry Point, on the north side of the swash channel, and northeastern side of the main channel.

*Point of Shoals and Jail Island Beds.*—The Point of Shoals beds lie to the northward and eastward of the Point of Shoals Light, and comprise an area of 14,941,000 square yards, approximately. They are bounded on the southward-and-eastward, southward, and southward-and-westward, by the main channel, the one-fathom curve of which clearly defines the limit of the bed, except for a mile and a half to the southward of the light. The northern boundary follows nearly the edge of the swash channel, which separates this bed from the Jail Island Bed; the latter lies to the eastward of the swash and northward of the main channel, and has an area, approximately, of 5,730,000 square yards.

Both the Mulberry Point and Jail Island Beds extend inshore as far as the sands which are found about at the one-fathom curve. The hydrography of the accompanying chart of the river was executed in 1874, and since that time very slight changes of depth of water can have occurred. It may therefore be accepted as giving the correct depth at the time of our examination. It shows that over the Mulberry Point beds the depth of water is from 1 or 2 feet in some places to 24 in others; on the Point of Shoals beds the same irregular bottom exists, the depth being from 2 feet to 30; and on the Jail Island beds from 3 to 16 feet are found. The soundings are given for mean low-water, the plane of reference; the mean rise and fall of the tides is 2.6 feet, and the maximum rise and fall 3.4 feet. The spring tides, however, fall 0.4 feet below the plane of reference, and consequently all the beds are subject to the grounding of ice of more than 16 inches thickness. As, however, the shoalest parts of the beds are situated on the boundary lines, they afford a certain amount of protection to the interior portions, the ice piling along the borders instead of lying in heavy masses upon the entire bed.

On the shoalest parts of the beds the bottom was found to be a stratum of shells with a light covering of mud and a substratum of hard sand. On these shoal places the oysters and shells were most abundant. The oysters were not evenly distributed over the entire bed, but grew in detached patches and ridges on and in the vicinity of the shoals, with numerous narrow mud sloughs intersecting and separating them. The deep water was found over these sloughs, and, generally speaking, the shallower the water the larger the number of oysters and the thicker and more solid the bed, this being especially true about the boundaries, where the beds rise abruptly from the main channel, and where great difficulty was found in attempting to penetrate them with the probe, while in the interior portions and in deeper water the surface stratum was of shells and mud, with 6 feet or more of soft mud underneath.

On the Jail Island beds the bottom was of shells and light, yellow mud, the stratum being about 4 feet thick; below it the bottom was mud. From the appearance of the shells I judged that they had been covered for some time; and that, combined with the unusual thickness of the shell stratum, leads to the opinion that this bed was receiving a larger amount of the sediment brought down by the river than either the neighboring oyster areas.

The oysters on the three beds are of the class known among the dealers as "snaps." They are small and poor, single or in small clusters of two or three, and when not transplanted are used for canning. There was no sponge or grass attached to the shells, and but very few of the usual inhabitants of a bed other than the oysters appeared to be present. Young oysters, of about one year's growth and under, predominated, and the proportion of young to mature oysters was greater on the shoal spots and ridges at the edge of the bed than elsewhere, owing, probably, to the fact that such portions of the bed being shoalest, hardest, and cleanest, they offered superior points for the attachment of the drifting spat.

The oysters from the Jail Island Bed were considered superior to any in the river for planting purposes, though no reason was assigned for the preference. The oysters from all these beds are generally transplanted before being sent to market. No oysters were found in the main channel, and in the swash channel only a few, and those widely separated.

Along the southwestern side of the river and main channel, in Burwell's Bay, and off Day's Point, are a few small beds, separated by large mud sloughs and many old "rocks" buried in the mud. The bottom is of red mud, with a substratum of mud or sand. The adjacent banks of the river are of red clay, and appear to be gradually washing away with the swift current of the river. The oysters found were older than those on the opposite beds on the Point of Shoals, but were of a poorer quality, and the beds are seldom worked on account of the scarcity and inferiority of the animals upon them.

*Blunt Point Bed.*—This bed consists of a number of small rocks of a few hundred yards area, with mud sloughs between them. The area of the bed is about 1,125,000 square yards, but as the bed does not rise abruptly from the channel, like those already described, thus allowing a ready and nearly correct definition of its outlines, the area given for it must not be considered as more than a rough approximation. In the case of the Point of Shoals and Mulberry Point Beds the channels and sands defined the limit of the oyster areas. In the case of the Blunt Point Beds the oysters are scattered in decreasing numbers from the center of the bed to the shores and channels, and the accurate or even approximately accurate delineation of the area covered by them would have required far more time than was at our disposal.

The bed is subject to a deposit of mud from the James River, but to a less extent than those beds already described; it also receives some sediment from the Warrick River. The bottom was found to be mud and shells on the surface, with a substratum of mud, except about the shoal places, where the substratum is hard, probably of sand. The contour of the bottom is more regular than that of the other beds, the depth of water as shown by the chart being from 7 to 8 feet.

The oysters were more numerous about the shoals and were distributed in a manner similar to those on the beds previously noticed, being collected in groups and patches separated by mud sloughs. They grew singly and in small clusters with no sponges attached and are of poor quality.

*Thomas Point, Kettle Hole, and White Shoal Beds.*—These beds are similar in character to the Blunt Point beds. The shoal portions embraced by the one-fathom curve show the original formation of the bed in the past, and mark what may be termed the backbone of the bed in the present.

The areas (approximate) are Thomas Point, 949,000 square yards; Kettle Hole, 1,792,000 square yards; and White Shoal, 1,300,000 square yards. The bottom on the Kettle Hole and Thomas Point Beds was found to be of mud and shells on the surface, the substratum on the Kettle Hole being of shell and sand, and on the Thomas Point Bed of mud, except when near the shoal spots. On both beds no oysters were found on the shoals when the falling tide exposed them, but great quantities of broken shells were mixed with the sand; on all contiguous parts the oysters were very thick. Away from the sand shoals the beds commence to be broken up by mud sloughs, and the oysters are found in groups, the size and number of the groups being inversely proportional to the distance from the shoal. The Kettle Hole Bed is nearer solid and uniform than the others, the rocks being larger and closer together. The depth of water over the beds is shown by the chart, and the same general conditions with regard to it that were noticed on those beds already described exist on those now under consideration. The covering of mud over the animals was quite light, and the beds appear to receive less of the sediment in the river than those above or on the opposite side of the channel. The oysters were single and in small clusters. Those from the Thomas Point Bed were small and of an inferior quality; those from the Kettle Hole were larger, of good quality, and with a moderate amount of white and gray sponge clinging to them, and on both beds the proportion of young oysters of less than a year's growth to those mature was very large.

*Bally Smash and Naseway Shoal Beds.*—The Bally Smash Bed lies between Goodwin Point and

Fishing Point, and about one mile off the southern shore of the river. Its area is (approximately) 984,000 square yards. The Naseway Shoal Beds lie NE. of Fishing Point, about the Naseway Shoals, and comprise an area (approximate) of 2,988,000 square yards. Both of these beds appear to have been originally formed about the shoals, those parts of the latter that are uncovered at low water showing a mass of shells broken and mixed with sand, and in their proximity the oysters are in greater numbers than near the margin of the bed. The depth of water on the Bally Smash Bed is about 4 feet; on the Naseway Beds it is the same, except in the mud sloughs, where the depth is from 6 to 8 feet. The Bally Smash appears to be an unbroken "rock," the bottom consisting of shells and oysters with a light covering of mud. The oysters were small and of the inferior quality known as "snaps." The strong current setting past and about the bed should have the effect of cleaning it, but the shoal, being dry at certain stages of the tide, appears to offer a barrier to the current in such a way as to cause a growth of the shoal to the northward and westward, where we found the largest amount of mud.

The Naseway Shoal Bed consists of a number of detached "rocks" separated by mud sloughs, except in the vicinity of the shoal, where the oysters were found in the largest numbers, and where the bed is comparatively unbroken. The "rocks" appear to follow the general direction of the shoals, and are in ridges and groups, scattering and becoming smaller in size as the distance from the shoal increases. The oysters were single, of all ages, and generally of poor quality, but inshore from the bed, where a number of small detached "rocks" known as mud and sand rocks are found, the oysters were larger and older in appearance, and the young growth was missing. The bottom on the Naseway Shoal was a thin stratum of mud and shells on the surface, with a substratum of mud, very thick in the sloughs, and of hard sand and shell in the vicinity of the shoals. The Naseway Shoal Bed is supposed to receive a larger amount of the sediment brought down by the ebb-tide than any other bed on the southern side of the river. As will be seen by the chart, the Eastern Shoal runs across the direction of the current, and the water deepens quickly to the eastward of the shoal. The "rocks" lie closer to the shoal on the eastern side than on the western, while the mud sloughs are more frequent on the western side than on the eastern. From the above it would appear that the western part of the bed received the larger amount of deposit, and that deposit was injurious to the oysters.

*Brown's Shoal Bed.*—The rocks composing this bed lie to the northward and eastward of the Naseway Shoals on the northern side of the river, and are situated, as their names indicate, on and about Brown's Shoal. The approximate area of the bed is 1,828,000 square yards. The depth of water is from 3 to 18 feet, the average depth about 8 feet, and the deep water is found as on the other beds, over the mud sloughs. The bed follows the general direction of the shoal, and is not so extensively cut up as those previously described. The bottom was of shell with a little mud, resting on a substratum of shell or hard sand. The oysters were single, and in small clusters, and were not evenly distributed, being thicker on the edge of the channel, where also was found the largest number of young. The oysters brought up having but little mud on them, and the soundings and probe discovering but a light covering of mud, it is presumed that there is comparatively but little deposit on the bed. The principal part of the sediment brought down on this side of the river is probably received by the Thomas Point and Kettle Hole Beds, and as we were informed that ice seldom grounded on Brown's Shoal, it is perhaps protected by the beds from that soil also.

### CRUISER'S ROCK AND NANSEMOND RIDGE.

Cruiser's Rock and the beds of the Nansemond Ridge are situated off Ragged Island, on the southern side of the channel, and about the shoals extending from Barrel Point. Their approximate area is 6,925,000 square yards. The beds are similar in character to those already described, being intersected by mud sloughs, and the oysters growing in groups and patches, but the mud sloughs are smaller and the area of the groups larger than on the other beds. The depth of water over the rocks is from 7 to 8 feet, and the surface stratum of the bottom consisted of shells and a small amount of mud. The substratum was, on the shoal parts of Cruiser's Rock, hard and of sand or shell; on the Nansemond Ridge of soft mud and shell for about 5 feet. The oysters found grew in small clusters or singly, and were of inferior quality. They were not found to the northward and eastward of the beds in greater depths than 15 feet, but exist to the eastward, scattered either in small groups or singly, as far as the channel into the Nansemond River. Inshore from the main beds are a number of small rocks and groups of oysters. From the character of the bottom on the Nansemond Ridge, it is inferred that there is a deposit of sediment accumulating on those beds, and from which Cruiser's Rock is free. The fact is that the position of the Naseway Shoals is such that they protect the upper portion of the ridge (Cruiser's Rock), while nothing interferes with the lower and middle portions, and the current out of the Nansemond River supports the inference. In addition there is a strong tide up along the Nansemond Ridge which would probably cause a deposit of any matter held in suspension. I was informed that these last-named beds were less exposed to the grounding of ice and its subsequent piling than any in the river. Attached to the oysters taken from the Nansemond Ridge was a variety of sponge, red in color, that was subsequently found on the Craney Island flats, and in large quantities in Tangier and Pocomoke Sounds. It is not often found where there is much mud or sand on the bottom, or where the oysters are scattered singly, and its presence is a good indication of a solid "rock," though its absence is not conclusive as to the non-existence of the same.

Between the Nansemond River and the channel into the Elizabeth River, and along Craney Island flats, are numerous small beds of unimportant area. They extend from the one-fathom curve out to about 2½ fathoms, growing in ridges and groups with wide spaces of mud between them. The oysters found were single and larger than any in the James River. There was also more red and gray sponge clinging to them than had been noticed before. The bottom was generally of mud and shells on the surface with, in the vicinity of the Elizabeth River, a hard stratum of sand and shells underneath, and in the vicinity of the Nansemond a substratum of mud. None of the beds are important and are only fished for the local market. The practice of depositing on the Craney Island flats the matter dredged out of the Elizabeth River and Norfolk Harbor is gradually destroying the beds inshore, and especially those near Craney Island.

### THE FISHERY AND ITS EFFECTS.

The oysters are removed from the beds in the James River with the tongs alone, no dredging being permitted, and this may account to some extent for the beds being made up of patches and ridges of oysters. This formation is only advantageous in so much as it assists the rapidity of the current, and in all other respects it is an evil. Beds such as Cruiser's Rock, Nansemond Ridge, and Point of Shoals, where the oysters in places are too thick, would be much improved by using a light scrape or dredge instead of the tongs in the fishery. If used with moderation, the surface of the bed would be cleaned, its area extended, the animals would be more evenly distributed and allowed more room for development, and the spat, having a larger and cleaner amount of "cultch" exposed, would probably attach in greater numbers. As, however, without stringent laws, rigidly executed, it would be impossible to keep the dredging within proper limits, and as there is but little prospect of such a thing occurring it is perhaps better, on the whole, that dredging is prohibited. The mud surrounding the beds is of too soft a character to permit any great extension of the present area, and thus one of the principal advantages of using the dredge would be lost while all its evils would be retained. Even as it is, the fishery is carried to excess, and all the beds, especially those in the neighborhood of Hampton Roads, are deteriorating.

### TANGIER AND POCOMOKE SOUNDS.

The charts showing the oyster beds and limits of oysters in these sounds have been constructed from the *data* collected during the progress of the work.

Only the natural beds are shown on them, and no attempt was made to carry the investigation beyond the sounds, except in the cases of the Manokin and Big Annemessex Rivers, where the beds were large enough to make their delineation and study advisable.

The beds have been named from the solid "rocks" which they surround, and are indicated on the charts by the darker shades. In many cases it was a matter of some difficulty to determine the outlines of the beds proper, on account of their peculiar formation. It would have given an erroneous impression to have considered either the solid unbroken portions as the beds, or to have taken the entire area upon which oysters are found, and I have therefore adopted the number of 0.1 oysters to the square yard as the standard by which to determine the outlines, all positions where the number fell below that standard being excluded from the beds, unless other circumstances have led me to a different decision.

The light shades on the charts show the area occupied by scattered oysters, and, as already explained, must be considered only approximate. The broken lines show areas where the oysters are very widely separated. The dark lines have been drawn through those positions where the number of oysters to the square yard was above the average.

In designating the oysters, the term "young growth" has been applied to the small oysters that were evidently but one year or one and a half years old. The term "young" has been applied to small oysters of the last brood that were found clinging to the mature oysters and old shells, and were, on an average, about one-half or three-quarters of an inch in length, or under.

Tangier Sound extends north and south, in round numbers, 36 miles, from Watts' Island to the head of Fishing Bay, and each side of the channel for 32 miles is lined with oyster beds of greater or less extent. These beds are continued, though the oysters are generally scattered, through Kedge's, Hooper's, and Holland Straits, and on the shoal between Smith's and Tangier Islands. On each side of the channels into the Nanticoke, Manokin, and Big Annemessex Rivers, beds are found, and to a less extent in the Wicomico and Little Annemessex Rivers.

By reference to the chart it will be seen that the only parts of the sound unoccupied by oysters are a short space, one mile in length, off Deil's Island, a space of two miles north of Jane's Island Light and between the Big and Little Annemessex Rivers, and a stretch of 2½ miles on the western side of the sound off Reach Hammock and the northern part of Tangier Island.

With these exceptions, the oysters are to all intents continuous, and the total area covered by them amounts to 69.12 square nautical miles.

The area of the beds proper, or that part of the total area on which the number of oysters to the square yard was at least 0.1, is 17.97 square nautical miles.

Whenever the names of the beds could be ascertained they have been given to them, but in some cases they could not be, and I have included them under general heads.

Taking them from the head of Fishing Bay in regular order, they are twenty-eight in number.

### FISHING BAY BEDS.

Under this head I have included all the beds lying in Fishing Bay, north of Clay Island Light-House, as they are subjected to similar influences of current, bottom, water, and temperature, and present similar characteristics. Most of the beds are of small extent, and many have special names; but the printing of the latter would encumber the chart, and consequently they have been omitted. Almost the entire bay, as far as Fishing Point, may be considered an oyster bed, oysters existing, though very irregularly distributed in groups of greater or less extent, over the whole area, except in the channel and close inshore. The groups, or "rocks," are represented on the chart by the dark shades, and are forty-three in number, comprising a total area of 3,600,000 square yards. The remainder of the space, 25,605,000 square yards, is occupied by small groups and patches of oysters, separated by large mud areas.

The beds or "rocks" become smaller as the head of the bay is approached; they grow about any marked shoal, and all are somewhat broken by small mud sloughs, especially about the edges. The center of each "rock," and noticeably on those in the middle and wider part of the bay, are comparatively solid, and about such places the oysters were found in greater numbers than near the mud sloughs and channel. In the northern part of the bay the depth of water over the beds is from 4 to 10 feet; over the southern part from 8 to 12 feet; the general depth, except in the channel, is about 11 feet.

The bottom in the northern part of the bay is hard, of shell mixed with mud, the stratum being from 4 to 6 feet thick, over a stratum of sand on clay. The bottom surrounding the beds was of mud. Soft, sandy bottoms were found along the shores, especially about Fishing Point and about the mouths of creeks. On the western, northern, and northeastern shores, marked "Planting Grounds" on the chart, the bottom was of clay with a light covering of mud on the surface. On the southern beds the bottom is a stratum of oysters and shells mixed with mud, 1 to 3 feet in thickness, over a stratum of mud, except in the southwestern part and on a small rock on the eastern side of the channel, near Clay Island Light-House, where the substratum is of sand. The rocks are surrounded, like those to the northward, by soft muddy bottoms, except in the case of those in the southwestern part of the bay, where the surrounding bottom is of sand; those beds having sand as a substratum were less broken than the others. In the channel the bottom was invariably of soft, dark mud.

On the northern beds of the bay the oysters were single and of small size, with many of recent growth and probably about one year old. No sponges and but few of the usual molluscan inhabitants of an oyster bed were discovered. On the extreme northern beds above Fishing Point, where the water is shoal, the beds old and much worked, the oysters are scarce, but on the other beds a very fair number were found. They were round and thin shelled and gave promise of developing into those of good quality, but the majority were too young at the time of our observations to be removed from the beds.

On the southern beds the oysters were larger and of a better quality than those to the northward, though the young growth still predominated. Some clusters were found, but generally the oysters were single and more plentiful than in the northern part of the bay, but the same sparseness of the fauna was noticed. In the southern portions, where the bottom is sandy, a moderate number of young and many *astyris* were discovered, and in the same part of the bay many oysters were found buried in the sand 3 or 4 inches. I was not able to ascertain whether that was their normal condition or not, but am inclined to think the sand was moved over them by a gale which occurred during the day previous to our examination.

A remarkable absence of young of less than a year's growth, and nearly a total absence of the drill, seem peculiar to the Fishing Bay beds.

*Were Point Bed.*—South of the Fishing Bay beds and north of Hooper's Strait Channel lies the Were Point Bed, comprising an area of 1,845,000 square yards. It is divided about the middle by a narrow strip of sand and mud into two irregularly-shaped portions, the upper one of which is similar in character to the Fishing Bay beds, though more broken. On both portions the oysters grow in groups and patches, separated by mud and sand sloughs, the separation being more marked about the edges of the bed. Oysters are found over the entire surface, but are not evenly distributed, the largest number on the southern portion being found along its northern and eastern border. The depth of water is from 9 to 15 feet, the general depth being about 11 feet. The bottom is of oysters and shells mixed with sand and mud, for about 2 feet, with a substratum of soft sand or mud. Where the groups occur the shell stratum is very thick, but is thin over and about the mud and sand spaces. Along the dark line on the chart, indicating the largest number to the square yard, the bottom is harder than elsewhere. The muddy bottoms were found principally on the eastern and southern portions of the bed, and the bed is bounded in those directions by bottoms of a similar character, while to the westward the contiguous bottom is of sand. The oysters were single, of moderate size and fair quality; very few young and no drills were found, either on the muddy or sandy bottoms; there was no sponge or grass among the oysters, and young growth of at least one year predominated. The scattered oysters near the bed were similar to those on it, though a few small clusters were found to the westward.

The number of oysters to the square yard, as given by the mean of fourteen measurements, is 1.25. On account of the shoalness of the water and softness of the bottom, the number is more nearly correct than usual, but it must be remembered that in this, and in all other cases, where the number to the square yard is given, that number only expresses "marketable" oysters, and does not include those which would not be accepted by a dredger, or which on account of want of age are practically incapable of reproduction.

*Shark's Fin Bed.*—Directly south of the Were Point Bed on the western side of the main channel and south of Hooper's Strait Channel, lies a bed of moderate size, but celebrated for the quality of its oysters, called the Shark's Fin Rock. It is regular in shape, extending ESE. and WNW. about one mile, and being about one-half mile broad. Its area is about 1,867,000 square yards. Practically, it joins the Were Point Bed at the southern extremity of the latter, the space separating the beds being very small. In the course of time through the action of natural causes and the dredges this space will be obliterated and the union of the beds made complete.

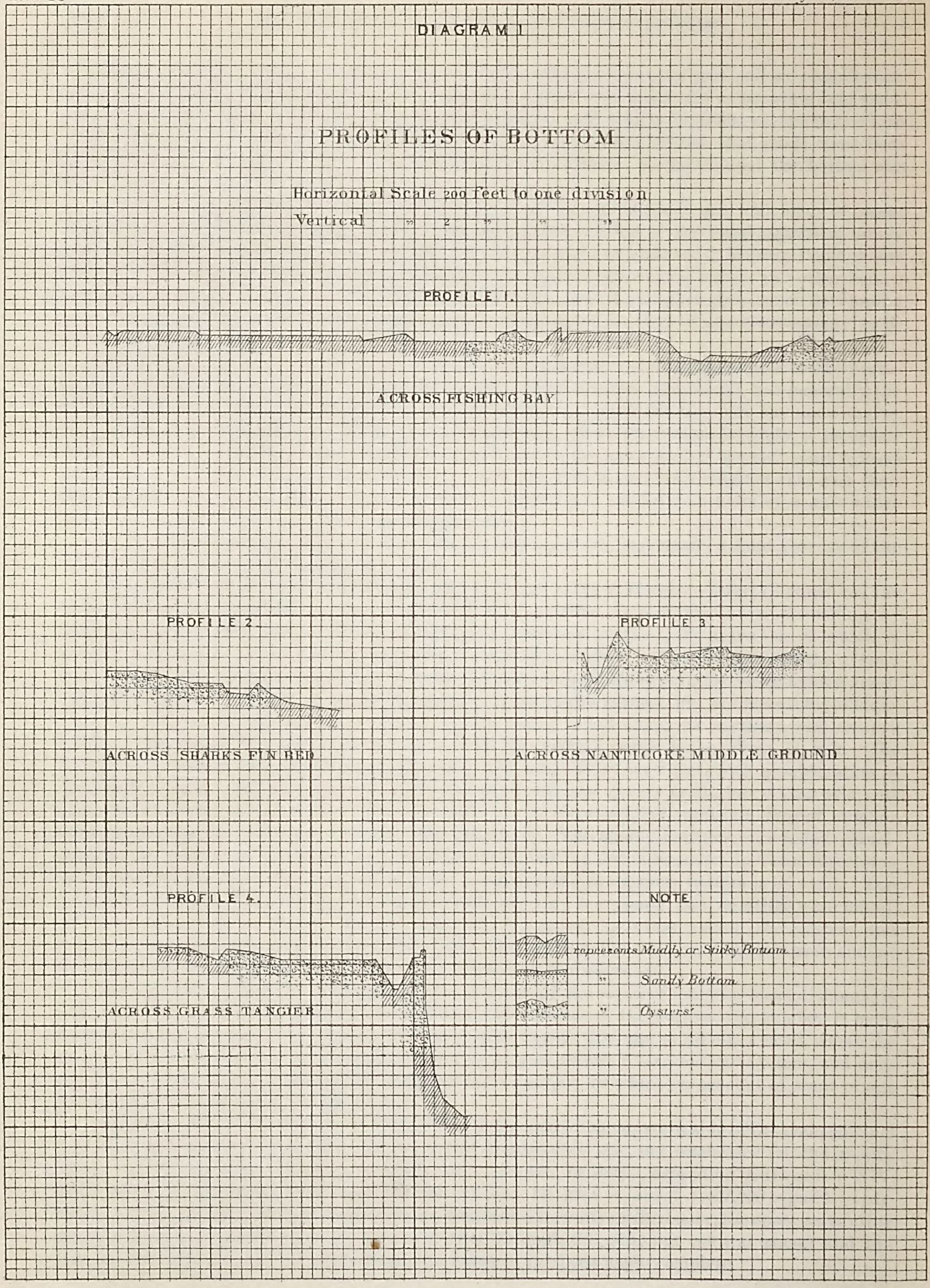


DIAGRAM I

PROFILES OF BOTTOM

Horizontal Scale 200 feet to one division

Vertical " 2 " " "

The Shark's Fin is a more compact bed than its neighbor, though about the edges, especially those bordering on the main channel, the oysters exist in groups, as on the beds already described. The animals are spread over the entire area, but are found in larger numbers about the central and more solid portions of the bed, and are scattered more and more widely as the borders are approached. The southern limit is not very well defined, scattered oysters extending farther in that direction than in the others. The depth of water is from 8 to 15 feet, the general depth being about 12 feet. The bottom is hard, consisting of oysters and shells with mud and sand for about 3 feet, and then a stratum of soft sand or mud. On the western part of the bed the shell stratum is much thinner and the substratum is hard sand. East of the bed the bottom, being that of the main channel, is of mud, and to the westward and southward of sand, soft near the bed, but growing harder as the distance from the bed increases.

The oysters were single, of a moderate size and fine quality. Very few young and no drills or other enemies were discovered, but the young growth of less than a year were found in large numbers, and also a little of the red sponge on the northern part of the bed. The scattered oysters were similar in character to those on the bed, though a larger proportion of young growth was found to the southward, and the same absence of "young" and drills was noticed both on muddy and sandy bottoms. On the bed the number of oysters to the square yard was 1.01. The number to the square yard on the area covered by scattered oysters west of the bed was 0.04, east 0.03, and south 0.03.

*Nanticoke Middle Ground Bed.*—On the middle ground between the channels into the Nanticoke and Wicomico Rivers there is a large bed of an area of 3,195,000 square yards, called the "Middle Ground Rock." It extends along the channel into the Nanticoke about 2¼ miles, and its greatest breadth is three-quarters of a mile. The bed is broken in many places, as will be seen on the chart, where only the larger divisions are shown, and the oysters grow in groups and patches of different areas with mud sloughs separating and intersecting them in all directions. The whole bed is broken up in this manner, but it is less noticeable on the northern and southern portions than on the central. The depth of water is from 8 to 21 feet, the deeper water being found along the western edge of the bed, where it borders on the channel, but, as the shoal rises abruptly, the parts of the bed covered by deep water are of small extent, and the general depth may be considered as about 11 feet. The bed is clearly defined by the channel of the Nanticoke on the west and the sands on the east. The bottom is a thin layer of mud over a stratum of shells and oysters from one-half foot to 5 feet in thickness. About the middle and western portions of the bed the substratum was soft mud, while on the northern, eastern, and southern portions hard sand was found underneath the shell stratum. The bottom on the central part of the bed in many places appeared to consist of alternate strata of shells and mud, and on the northern and southern parts the general character of the bottom was much harder than on the central portion. To the northward and eastward of the bed the bottom was of hard sand or fine gravel, and probably the lowest stratum of the bed bottom, could it be reached, would be found of similar nature. South and west of the bed and in the channels the bottom is soft mud. Only a few oysters were found in the channel into the Wicomico, and none in that into the Nanticoke.

The oysters were generally of an inferior quality and small size, and grew singly and in small clusters, though the number of the former was comparatively small. No young were found, but many young growth, probably about one year old, and no sponge, grass, or drills. Along the edge of the Nanticoke Channel the shells were blackened, probably by the mud. On the west side of the Nanticoke Channel, north and east of the one-fathom sand shoal, there are a few small beds, comprising a total area of 270,000 square yards. The depth of water over them is from 4 to 8 feet, and they are unbroken but separated from each other by spaces of mud or sand. Over these spaces the depth of water increases. The bottom is a stratum of shells, about one foot in thickness, over a stratum of sand and clay. A light covering of mud lies on top of the shells. The oysters were single, with many of a young growth. Many shells, but no young or drills, were found. West of these beds and southeast of Clay Island light the oysters are very thinly scattered, in small groups or singly. The three-fathom curve approximately defines their limit to the southward and westward, and the one-fathom curve the northern limit. The bottom is of mud or sand, the latter being found inshore.

*Clump Point Rocks.*—These are small beds lying on each side of the channel into the Wicomico River and between Long and Clump Points. They are of small area, comprising collectively but 382,500 square yards, and lie in from 5 to 10 feet of water; they are separated from each other by the muddy bottoms of the channel or sloughs. All the rocks are broken in many places, the oyster groups separated by spaces of mud and sand, the latter species of bottom being found principally near Long Point. On the rocks the bottom is of shells and mud, with a substratum of mud. Very few oysters were found on the bottoms surrounding the rocks, and those discovered grew in small groups, the number and size of which decreased very much to the eastward of Long Point. The oysters were very scarce and resembled those of the Nanticoke Middle Ground in general character, though a larger number of single ones were found than on that bed.

*Horsey's Bar and Tyler's Rock.*—These are comparatively small beds, lying on the southern side of the Nanticoke Channel, southwest of the Middle Ground and north of Haine's Point. The first bed extends north and south three-eighths of a mile and east and west one-eighth of a mile. Its area is 202,500 square yards. The second bed lies southwest of Horsey's Bar, and is one-half mile in length and breadth, and comprises an area of 675,000 square yards. Both beds are unbroken, except about the edges, and on the major portion of each bed the oysters are evenly distributed. Along the northern and southern boundaries, where the beds border on the channels, the oysters are found in groups, separated by mud sloughs. The depth of water over Horsey's Bar is 12 feet, over Tyler's Rock from 14 to 16 feet. The bottom consists of a stratum of shells from 1 to 2 feet in thickness, on a stratum of hard sand; on top of the shells was a light layer of mud. The oysters were small, single, and of poor quality, and those of one year's growth predominated. No young, drills, sponges, or grass were found on the beds.

*Drumming Shoal Bed.*—This bed lies on and about the shoal off Haine's Point, from which it derives its name. It is one mile and three-quarters long and three-eighths of a mile wide, and extends in a northeasterly and southwesterly direction along the eastern edge of the main channel of the sound. Its area is 2,430,000 square yards. The bed is unbroken, the central and southern portions being remarkably hard and solid. About the edges, as with the other beds, it is intersected by mud sloughs, and the oysters grow in the usual groups and detached patches, but generally they are evenly distributed, a slight difference existing in favor of the shoaler and central part of the bed lying on the Drumming Shoal.

The depth of water is from 10 to 20 feet, the deeper water being found on the northern part and along the western border. The major portion of the bed has but 11 feet over it. On nearly the whole bed the bottom consists of a stratum of shells with a light covering of mud over a stratum of hard sand. On the extreme northern part the substratum was mud, and the surface stratum of shells not so thick as elsewhere. The oysters were single and in small clusters; a moderate number of shells and a little of the red sponge was found. Inside of Drumming Shoal is a small bed called Haine's Point Rock, which has been included in the description and area given for the Drumming Shoal Bed, with which it is closely connected.

*Cedar Rock.*—This bed lies about one-half mile south of the Drumming Shoal and comprises an area of 337,500 square yards. The depth of water over it is from 12 to 17 feet and in all respects it is similar in character to the Drumming Shoal Bed.

On the western side of the sound, along the edge of the channel, the beds are nearly continuous from the Shark's Fin to the Terrapin Sands, a distance of about 11 miles. This space was originally divided into three portions, each locality having a particular designation, but at present it is difficult to define their limits, the spaces separating the beds having gradually diminished until they practically have ceased to exist. The dark lines on the chart indicate the positions where the largest numbers of oysters are found, and will show approximately the situation of the original unbroken "rock" from which the locality derives its name. The oysters taken from this region are known in the market as "Grass Tangiers" and have a good reputation, both for size and flavor.

*The Cow and Calf Beds.*—These are two small beds lying on the edge of the channel and south of the Shark's Fin. This area is 292,500 square yards. The smaller bed, called the Calf, has from

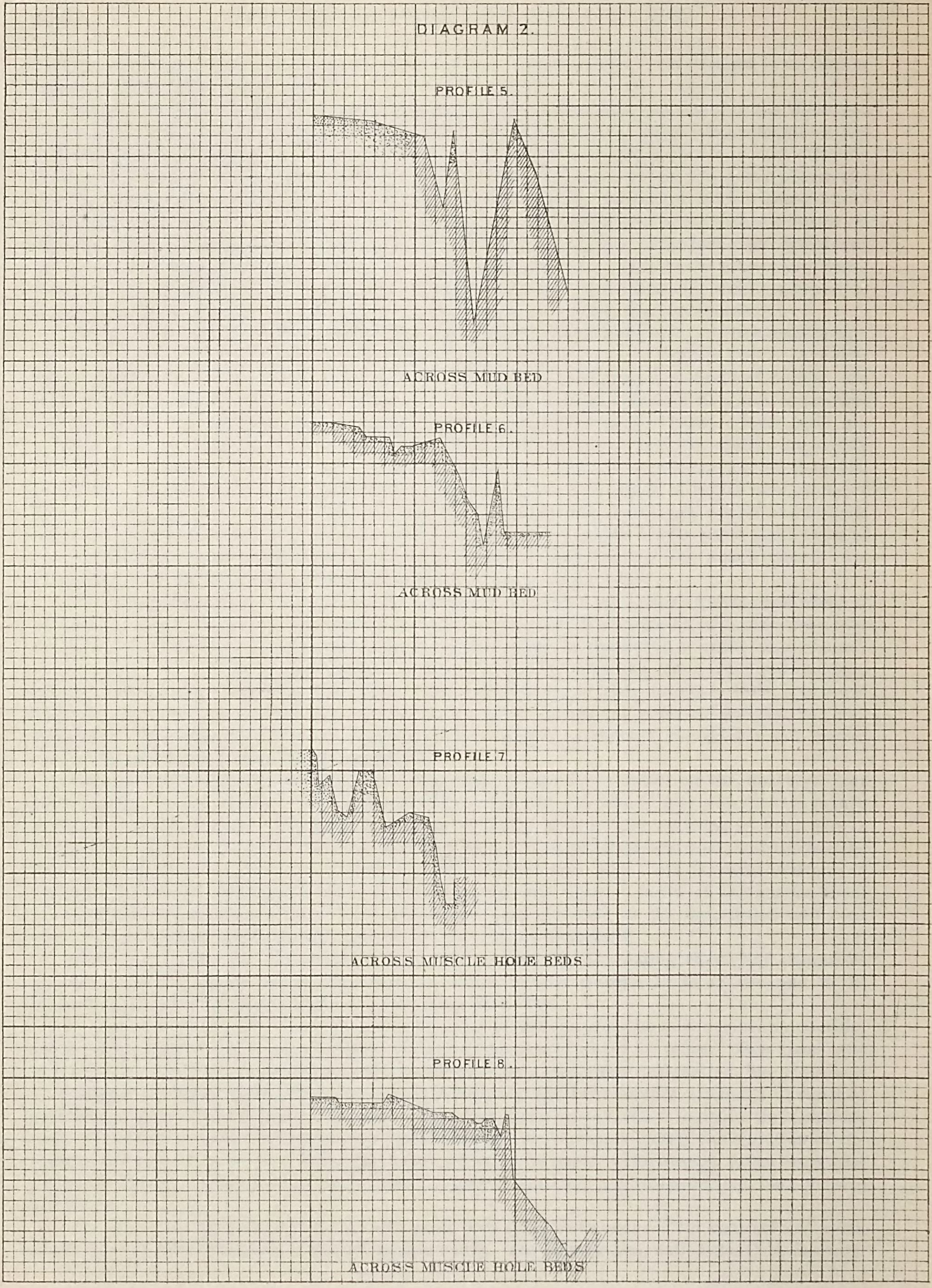


DIAGRAM 2.
PROFILE 5.
ACROSS MUD BED
PROFILE 6.
ACROSS MUD BED
PROFILE 7.
ACROSS MUSCLE HOLE BEDS
PROFILE 8.
ACROSS MUSCLE HOLE BEDS

9 to 16 feet of water over it; and the larger bed, the Cow, has from 9 to 11 feet. The beds consist of large groups of oysters separated by mud sloughs; the "rock" itself is a very hard and thick stratum of oysters and shells, into which we could not force the probe more than 2½ feet. The oysters were small, with about two-thirds of young growth; neither young nor drills were found. The number of oysters to the square yard was 1.51, which is probably more nearly correct than usual, the hauls of the dredge being made under exceptionally favorable circumstances.

On the western side of the channel and Sound and due east of the southern part of Bloodsworth Island is a large bed, the name of which we were unable to ascertain. It is two miles long, extends north and south, and is from two-eighths to five eighths of a mile wide. Its area is 4,027,000 square yards. The eastern part of the bed is unbroken, but the western portion and the extreme eastern border are cut up by mud sloughs, which separate the oysters and leave them in groups of different sizes. Along the eastern part, almost immediately after striking the bed, we discovered a shoal ridge about 200 yards wide, which was unbroken and had a depth of water over it of 10 or 11 feet. To the westward of this ridge the water deepened quickly 3 or 4 feet, but the general depth of water over the bed is from 10 to 14 feet. The oysters are distributed over the entire area, but unevenly, the largest number being found on the central and southern portions of the bed. The bottom was found to be generally a stratum of shells, oysters, and mud, of about one foot in thickness, over a stratum of mud. Along the shoal ridge oysters and shells were found as far as the probe could penetrate. To the westward of the bed the bottom is soft sand or mud, the sand predominating and becoming harder as the shores of the island are approached. To the eastward the bottom is soft mud. The oysters were single and of moderate size. Large numbers of young growth, but neither young nor drills, were discovered. A little red sponge was found on the eastern edge of the bed. To the southward of the bed the oysters were larger, but not so many of recent growth were found, while to the westward the scattered oysters presented similar characteristics to those on the bed, and the same absence of young and drills was also noticed. The number of oysters to the square yard, the mean of ten observations, was 1.06.

*Turtle Egg Island Bed.*—This bed is situated on the western side of the channel, off the small island from which it derives its name. It is irregular in shape, extending along the edge of the channel in a NNE. and SSW. direction about 1¼ miles, and is from one-quarter to one-half mile broad. Its area is 1,620,000 square yards. The bed is unbroken about the center, but narrow mud sloughs intersect the northern, eastern, and southern portions; to the westward the oysters are scattered; on the eastern border of the bed they are more numerous than elsewhere. The depth of water over the bed is from 10 to 23 feet. A ridge similar to the one on the bed immediately to the southward was found along the eastern edge with a depth of water over it of about 12 feet; to the westward of the ridge 14 and 16 feet were found, and to the eastward much deeper water. The surface stratum of the bottom generally consisted of shells and oysters mixed with mud or sand; on the eastern portion of the bed the substratum was mud, while on the western and northern portions it was sand. East of the bed the bottom was soft mud; west of it soft sand on top of hard sand. The oysters were single, a few of large, but most of moderate size, of good quality, and many of recent growth. Neither young nor drills were found. A little red sponge was brought by the dredge on the SE. border, and a good deal of grass was found on the sands to the southward and westward of the bed. Very few oysters were found to the westward. East of the bed, on the small rock in deep water, many young growth, but no young, were discovered. The number of oysters to the square yard on the bed, as given by the mean of thirteen observations, was 0.38. On the small rock referred to above, the number to the square yard was 1.30.

*Mud Rock.*—This bed lies on the western side of the channel, south of the Turtle Egg Island Bed, and east of South Marsh Island. It extends north and south about 1½ miles, and is from one-quarter to one-half mile broad. Its area is 1,845,000 square yards. The bottom is very irregular, the depth of water being from 12 to 34 feet. The ridge along the edge of the channel was not as prominent as on the two beds previously described. The bed is broken in many places by mud sloughs, and about the eastern portion especially, where the oysters are in groups and patches. In the vicinity of the line showing where the largest number of oysters exist, the bed is more solid and the bottom harder than elsewhere. As this line crosses the bed three times, and from other circumstances, it is concluded that the distribution of the oysters is irregular, and the conclusion is supported by the evidence of the sounding pole and probe. East of the northern part of the bed, in the channel, are two small shoals with 12 feet of water on them. On and around them small oyster beds have formed, and between the shoals and the main bed oysters are found scattered in groups in water as deep as 8 fathoms. On the main bed the bottom is a thin stratum of oysters and shells resting on mud or sand. East of the bed soft blue mud was found, and to the westward mud, shells, and sand. The oysters were large, single, and in small clusters, and of good quality; the largest oysters were found on the soft muddy bottoms; the number of young growth was smaller than on the beds previously described, while the number of young was larger; a few drills were found about the edges of the bed and a moderate amount of red sponge. On the small beds in the channel the oysters were principally of recent growth. East of those beds a good deal of grass was found, and also in the deep water between the shoals and main bed.

*Chain Shoal Bed.*—This bed lies on the eastern side of the channel, abreast the Lower Thoroughfare and Little Island. It extends north and south 1½ miles, is from one-eighth to three-eighths of a mile wide, and comprises an area of 1,192,000 square yards. It is unbroken, except about its western border, where the oysters are found in groups; to the eastward the sands, on which are scattered a few single oysters, clearly define the limit of the bed in that direction. The bottom is irregular, the depth of water being from 12 to 19 feet, and the upper stratum consisted of shells, oysters, and mud; the substratum was of hard sand. The surface stratum was from 1 foot to 4 feet thick, and, with a diminished amount of sand, increased in thickness on the southern part of the bed. The surrounding bottoms are of sand, though on the western side the mud of the channel approaches the bed closely. The oysters were of moderate size and fair quality. The mature oysters were single; those of recent growth, a large number of which were found, were single and in clusters, the latter predominating. Very few young were discovered, and very few drills (*astyris*); the latter were located principally on the southern part of the bed. A large amount of red and gray sponge was found on all parts of the bed. The oysters on the contiguous bottoms were similar to those described on the bed.

*The Muscle Hole Bed.*—This bed lies on the western side of the channel, south of the Mud Rock. It extends north and south about 3 miles, is from one-half to one-quarter of a mile wide, and comprises an area of 3,060,000 square yards. It is very irregular in shape, and at about two-thirds of its length to the southward it is cut in two by a mud slough. The depth of water is from 12 to 34 feet, and the bottom very irregular, especially about the northern portion, which is cut up into shoals of shells and oysters separated and intersected by narrow mud sloughs, over which the oysters are thinly spread. About the central portion the middle of the bed is comparatively solid, but the eastern and western portions are similar to the northern. The southern part is also broken up considerably, but the bottom is not as irregular as elsewhere. The bottom consists of a stratum of oysters and shells mixed with mud and sand, from one-half foot to 2 feet in thickness, resting on a stratum of hard sand. The shell stratum was thicker along the western part of the bed, where the dark line is drawn on the chart, and decreased in thickness as the eastern edge was approached, where it was hardly observable, and where a substratum of mud was frequently found. East of the bed the bottom is soft mud; to the westward soft sand or sticky mud, with usually a hard substratum. The mature oysters were large and single and of good quality. A very large proportion of young growth was noticed, at least one-half the oysters being of that description. A large number of young, but few drills (*astyris*), were found on the hard bottoms of the central part of the northern portion. On the central and southern portions of the bed the number both of young and drills decreased, while they increased greatly on the western portion. A large amount of red sponge was found, and in greater quantities about the edges of the bed, especially the western, than elsewhere, but its presence appeared to have no effect upon the young or drills. East of the bed the oysters were of the same general character as those on it; the same proportion of young growth was also noticed, but there was almost an entire absence of young and drills. To the westward, as a rule, the oysters were somewhat larger than those on the bed, but as many young growth were present as elsewhere. The number of young and drills was, however, much diminished, as was also the amount of red sponge. The number of oysters to the square yard, the mean of thirty-six observations, was 0.70. The number to the square yard on the area occupied by scattered oysters, the mean of seventeen observations, was 0.07.

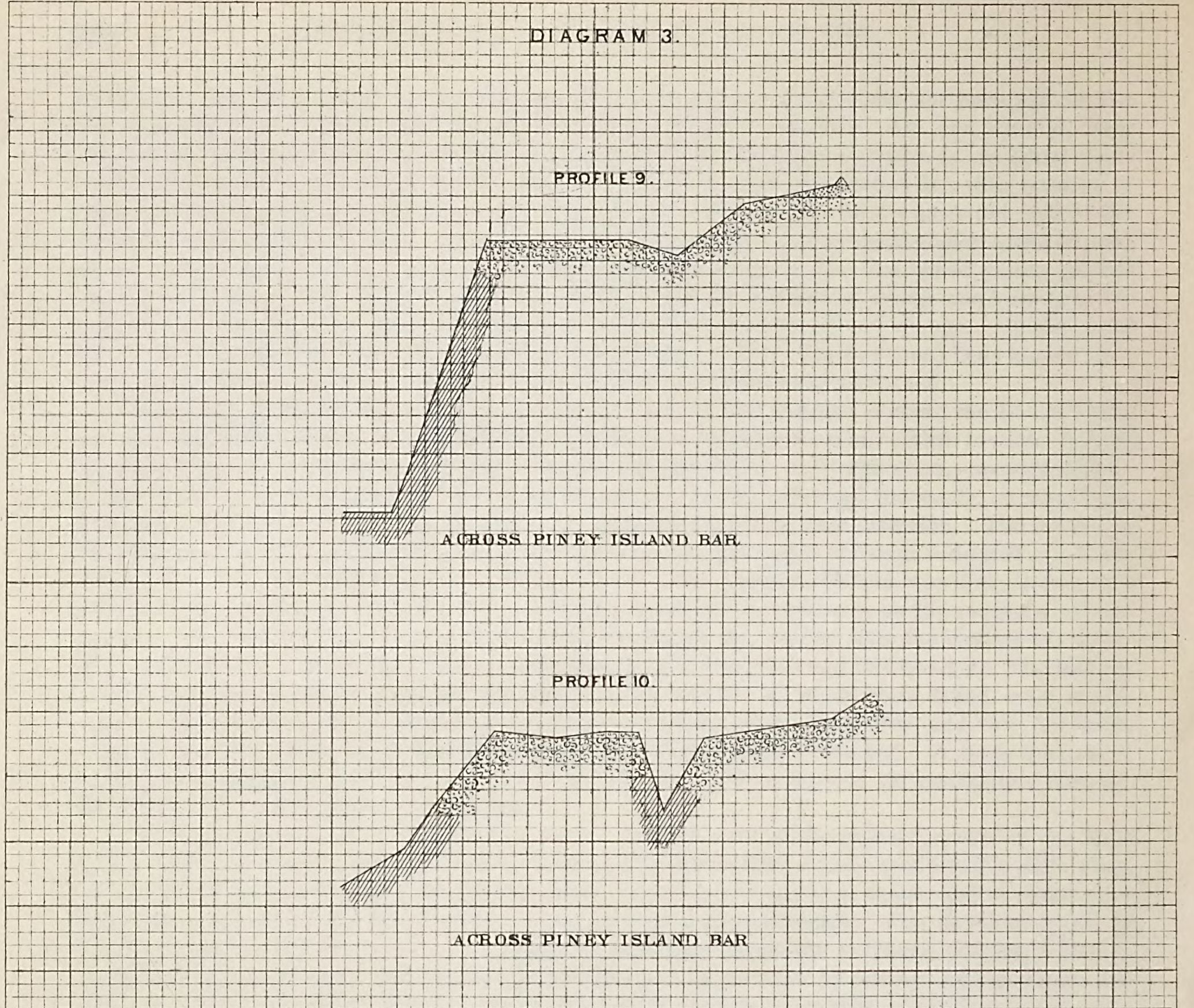


DIAGRAM 3.

PROFILE 9.
ACROSS PINEY ISLAND BAR
PROFILE 10.
ACROSS PINEY ISLAND BAR
PROFILE 11.
ACROSS MANOKIN RIVER UPPER BEDS
PROFILE 12.
ACROSS MANOKIN RIVER LOWER BEDS

*Piney Island Bar.*—This bed lies south of Little Island, on the eastern side of the channel and on the western side of the shoal lying between the main channel of the Sound and the channel into the Manokin River. It extends NNW. and SSE. 3 miles, and its greatest breadth, which is near its southern extremity, is about one mile. The bed gradually diminishes in size to the northward, and at that extremity is but one-eighth of a mile wide. Its area is 6,975,000 square yards, and it is unbroken, with the exception of a few sand spaces in the southern portion and a smaller number of mud areas in the northern. About the extreme western border the oysters are in detached groups, with mud sloughs between them, and to the eastward and southward the oysters are more widely scattered and scarce, until they reach the sands or soft muddy bottoms of the channel, when they entirely disappear. The depth of water is from 12 to 36 feet, and, generally speaking, the deeper water will be found on the western and the shoaler on the eastern parts of the bed; there are several holes and sloughs, however, about the middle of the bed. The oysters are not very evenly distributed, as will be seen by the lines on the chart, which indicate the positions of the greatest number, and in the vicinity of the sand and mud areas a smaller number of oysters were found than elsewhere. The bottom is hard, except about the extreme western edge, in deep water, and about the mud holes and sloughs situated in the northern portion. Owing to the depth of water the observations of the character of the bottom were not as numerous as on other beds, but those that were made showed the existence of a stratum of shells and oysters of from one-half foot to 4 feet in thickness, and mixed with mud and sand, over a stratum of hard or soft sand, the former predominating. West and south of the bed the bottom is mud or sticky sand, the latter being found more frequently to the southward than westward. To the eastward the bottom is hard sand. The oysters were single, of moderate size and ordinary quality. A very large proportion—fully one-half—were young growth. Few drills and not many young were found, and both young and drills were in greatest numbers about the extreme southern part, and in least numbers about the northern. A moderate amount of red and gray sponge was found on all parts of the bed, and some of the sponge on the sandy bottoms south of it; where the young oysters were in greatest numbers the amount of sponge was least. West of the bed very few oysters were found, the "rock" rising abruptly from the channel. South and east of the bed the oysters were scarce, and the amount of sponge and grass much increased. The number of oysters to the square yard, the mean of forty-nine observations, was 0.69. The number to the square yard on the area occupied by the scattered oysters was 0.04.

*Beds of the Manokin River.*—These beds lie on each side of the channel of the Manokin River and extend about 4½ miles from its mouth. The investigation extended as far as Saint Pierre Island, above which point only a few small "rocks," of inconsiderable area, were found. The beds are fifteen in number and comprise a total area of 6,142,000 square yards. Generally speaking, the larger beds are on the northern side of the channel. By reference to the chart it will be seen that beds of more or less area are distributed over the entire river bottom, being separated and intersected by numerous mud sloughs. The character of the individual beds is similar, each being cut up by mud sloughs and divided into small groups and areas of oysters, thus on a small scale reproducing the whole river bottom. The depth of water is from 8 and 10 feet on the upper beds to 27 feet on those off Hazzard's Point. In the channel the depth is 25 and 30 feet off Hazzard's Point, shoaling gradually to Saint Pierre Island, where there is about 13 feet, though there are many deep holes and sloughs where the depth exceeds the average. On the beds the bottom is very irregular, and the change from shoal to deep water sudden and frequent. Generally a thick stratum of oysters and shells were found on the shoals, and where the water deepened a large amount of mud. The oysters appear to be in larger numbers on the beds about the mouth of the river than elsewhere, are very thinly scattered in groups in the channel, and on the extreme upper beds are very scarce. The bottom consists of a stratum of shells and oysters, from one-half foot to 2 feet in thickness. On the northern side of the channel, near the sands, a stratum of hard sand is found directly underneath the shells, but nearer the channel and on its southern side there is an intervening stratum of mud from 1 to 4 feet thick. On the greater part of the beds the oysters and shells are mixed with mud, but in the extreme southwestern portion soft sand is found instead. Many of the beds in the upper part of the river are covered by a stratum of mud about 1 foot thick, and near the southwestern border the oysters and shells were covered by 3 to 6 inches of sand. In running lines across the river a similarity was frequently noticed in the character of the succeeding surface strata to those of the bottom, as shown by the probe. For instance, in the channel soft mud was found; proceeding inshore a surface of shells and mud, then one of mud or soft sand, and, finally, hard sand was encountered; the bottom on the major portion of the bed is built of similar strata, arranged in reverse order, the hard sand being the lowest. The oysters in the upper part of the river were single and in small clusters; most were young growth, and all were of inferior quality. But few young and few drills were found, and no sponge or grass. On the southern beds the animals increased in size and numbers and improved in quality; a large proportion of young growth was still present, and a larger number of young and drills; a small amount of sponge and grass was found. The scattered oysters in the channel and on the sands were of the same character as those on the beds, but no young, drills, or sponge were discovered.

On the extensive sand shoal south of Piney Island there are no oysters, but much sponge and grass.

The observations for ascertaining the number to the square yard were made only on the southern beds, and consequently must not be considered as giving a just average for the whole area. On the beds, the number to the square yard, the mean of twenty-five observations, was 0.90; on the area occupied by scattered oysters, 0.13.

### BEDS OF THE BIG ANNEMESSEX RIVER.

In this river and about its mouth, and on both sides of the channel, are ten beds. The largest are the western ones, situated off Flat Cap Point, and from thence to the eastward the beds gradually decrease in size. They comprise a total area of 2,835,000 square yards.

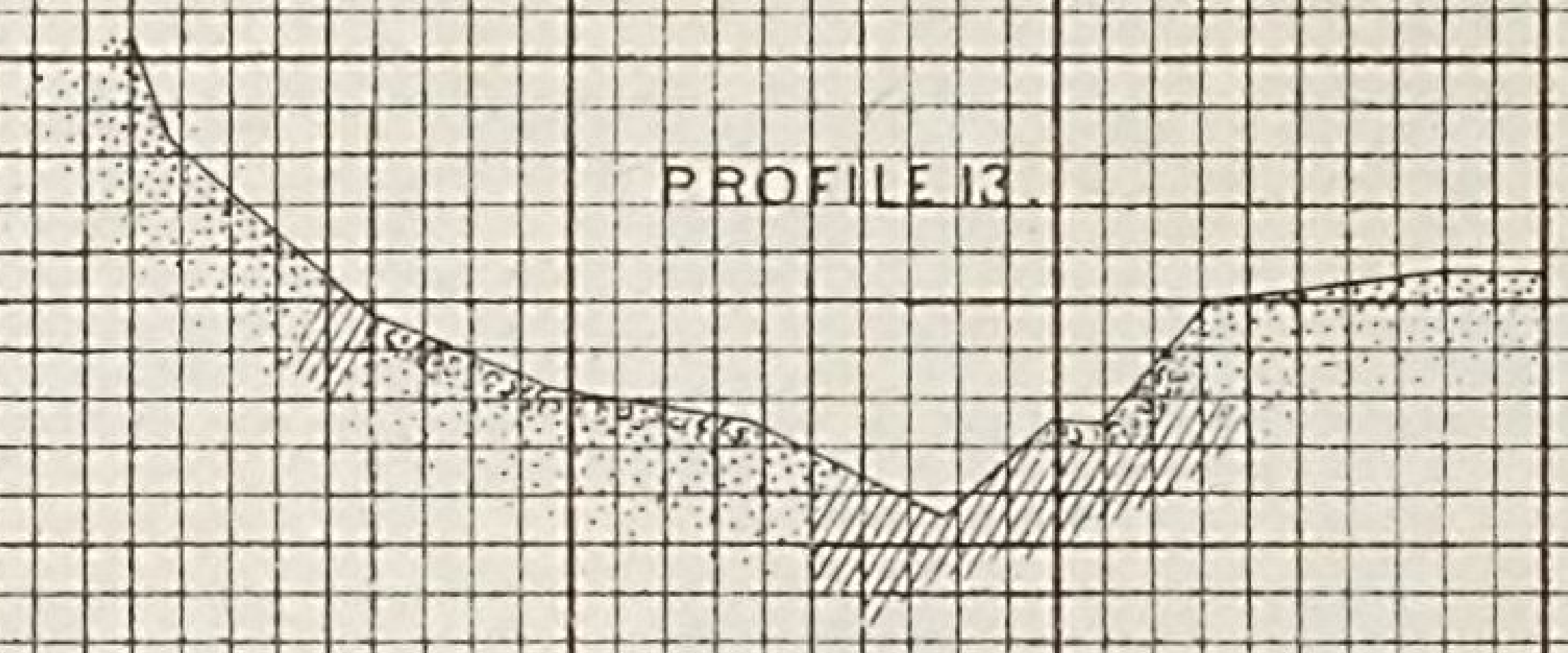
Though the beds are distributed over the river bottom in a manner similar to those in the Manokin, there is little or no similarity in other respects, except between the western parts of the beds in the mouth of the river and where those farther to the eastward are in proximity to muddy bottoms. In these cases the beds are broken up by sloughs and the oysters piled up about the shoal spots much in the same manner as in the Manokin. The beds in the mouth of the river, especially where they come in contact with muddy bottoms, are also broken by sloughs and the oysters separated into groups. Most of the beds, including nearly all *in* the river, are comparatively unbroken. They are surrounded by sandy bottoms, and, except near the channel where there is mud, such few sloughs as run into them are of sand.

The western beds have from 16 to 33 feet of water over them, and the eastern beds from 7 to 13 feet. Generally speaking, the depth of water may be considered as about 14 feet. The bottom consists of a stratum, about 6 inches thick, of oysters, shells, and soft sand or mud over a stratum of hard sand. The surrounding bottoms consist of strata of soft sand on hard sand, except in the channel where the surface stratum is mud. More mud on the surface was found on the western beds than the eastern. The oysters were small, single, and in small clusters, of poor quality, and with few young, and no drills (*astyris*). A small amount of sponge was found, and the oysters taken in the vicinity of the mud sloughs had blackened shells. The number of oysters to the square yard on the western beds, the mean of seven observations, was 0.56.

*Harris Bed.*—This is a large bed lying off Flat Cap Point, on the eastern side of the main channel of the Sound, and across the channel into the Big Annemessex River. It extends north and south 2½ miles, and its greatest width is a little more than one mile. Its area is 3,420,000 square yards. The bed is broken in many places, and is separated into four distinct portions by broad spaces of sand that intersect it. All of these portions are more or less cut up by mud or sand sloughs, and especially the middle and larger portion, which contains within its limits several large areas that are occupied by scattered oysters only. The northern portion of the bed is broken by many mud sloughs, and the oysters grow in patches of small area. The other portions are as represented on the chart, the groups of oysters being large and comparatively solid, and the separating sand spaces of more considerable area than where they were of mud. As will be seen by referring to the dark lines on the chart, the oysters are not evenly distributed, but they are found in larger or smaller numbers on the entire area. The bottom is irregular in contour, as will be noticed by reference to the depths of water plotted on the charts. On the northern portion the

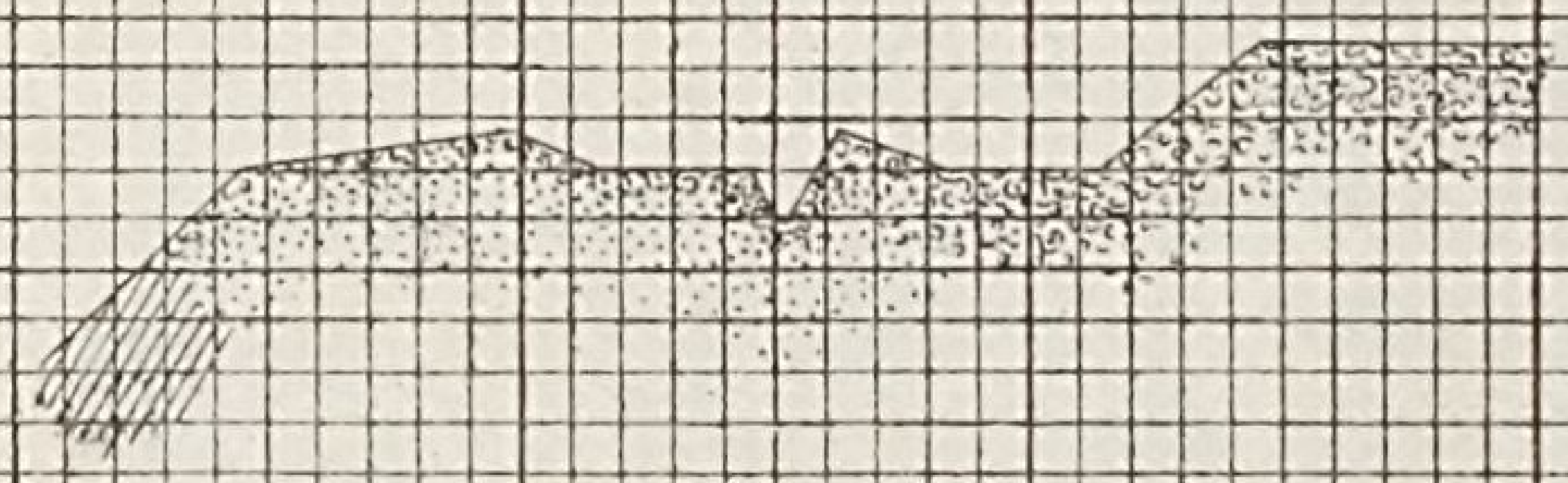
# DIAGRAM 4.

PROFILE 13.



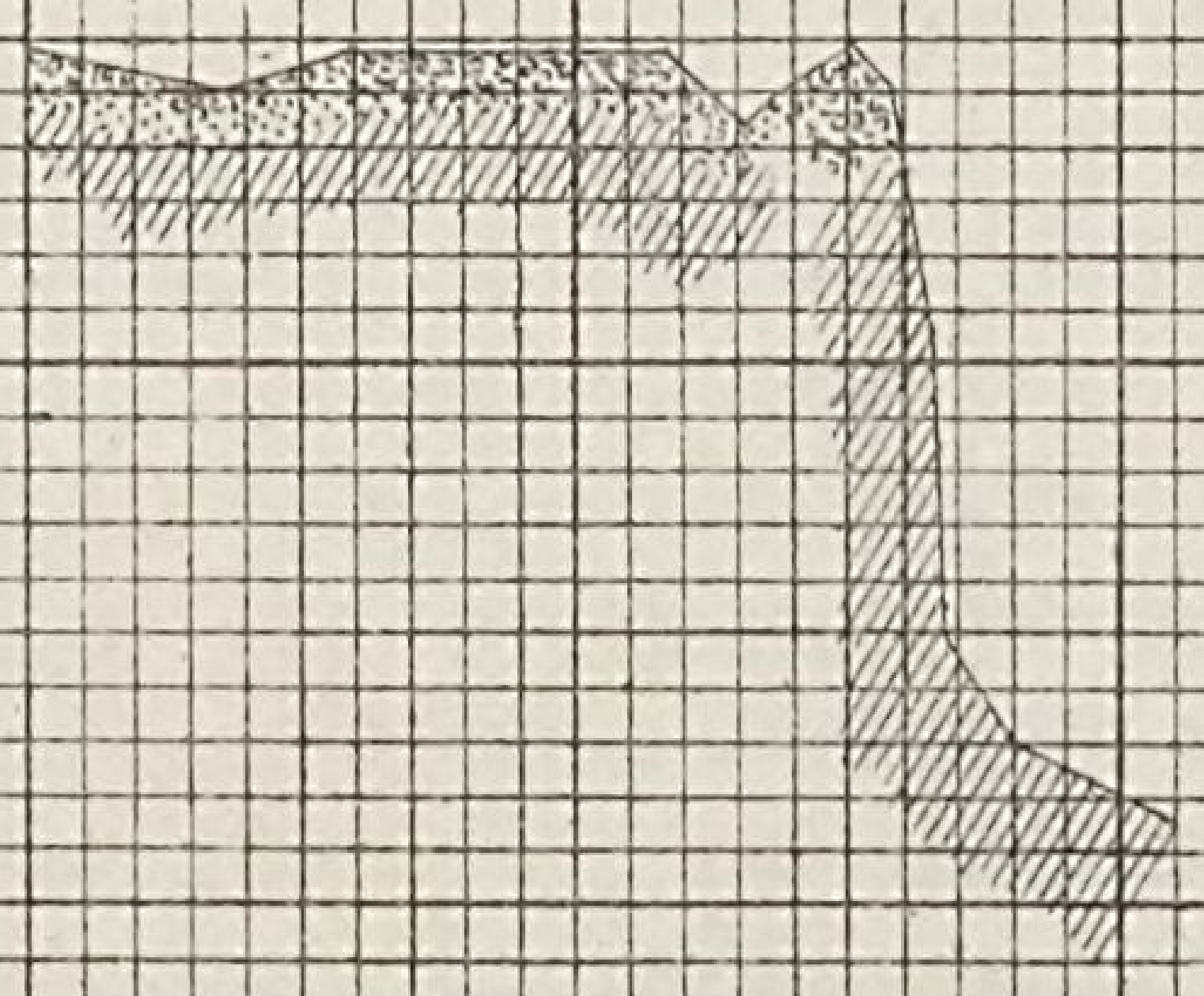
ACROSS ANNEMESSEX RIVER BEDS

PROFILE 14.



ACROSS HARRIS BEDS

PROFILE 15.



ACROSS TERRAPIN SANDS

depth is from 17 to 33 feet, on the central portion from 16 to 24 feet, and on the southern portion 19 to 28 feet. On account of the depth of water over the bed, only a few observations of the character of the bottom could be made, but a sufficient number were obtained to show that it consisted, generally, of a stratum of shells, oysters, and sand, of about 2 feet in thickness, over a stratum of soft sand. The bottom of the northern portion and in the Annemessex Channel was softer, and mud was found on the surface in the place of sand. Except on its northern border, the bed is surrounded by sandy bottoms, though the mud of the channel is not far distant from the western edge of the bed. The oysters were of all sizes and qualities; those on the northern portion were in small clusters and of small size. A few young and a few drills, with a moderate amount of sponge, were found. On the eastern part of the bed the oysters were single, large, and of good quality. Very few young, but few drills, and a moderate amount of sponge and grass were found. On the central parts of the bed the oysters were of moderate size and fair quality. About the middle of the larger portion were an immense number of "young" and a moderate number of drills. Many of the young were injured by the dredge and a large number by drills. A good deal of red, gray, and white sponge was found, but its presence did not apparently influence the number of young on the extreme southern part of the bed, though an unusually large amount of grass and sponge was discovered, and a few drills, yet the number of young was also large. On the western portion of the bed fewer oysters were found, and a smaller number of young and drills. There was no increase of sponge or grass. The scattered oysters east of the bed were large, single, and in small clusters, with a moderate amount of sponge and grass, a few young, and a few drills. To the westward very few oysters were found, but a good many shells and red and gray sponge were brought up by the dredge. It will be noticed that the "strike" or "set" of "young" on this bed was confined to the center of the largest portion, and that very few "young growth" were found on or about the bed, though they were in large numbers a few miles to the northward in the Manokin River. The number of oysters to the square yard, the mean of forty observations, was 0.28. The number on the area occupied by scattered oysters, the mean of twenty observations, was 0.06.

*Terrapin Sands Bed.*—This is a long narrow bed lying on the shoal from which it derives its name. It is on the western side of the channel, south of the Muscle Hole Bed and Hedge's Strait and opposite Harris' Bed. It extends northwest and southeast 3¼ miles, and is, on an average, from one-tenth to one-quarter mile wide. It comprises an area of 1,417,000 square yards. It is divided by spaces of mud and sand occupied by scattered oysters into four distinct portions, the southern one of which is separated from the main bed by a sand space of one-half mile. The northern portion is similar in character to the southern part of the Muscle Hole Bed, the oysters growing in groups and patches, separated by soft bottoms. The remainder of the bed is less broken than any in the Sound, being entirely free from mud and sand sloughs, except about the borders. The oysters are distributed over the entire area, but are in larger numbers on the main and central portion and in smaller numbers on the northern portion than elsewhere. The bottom is irregular, the depth of water ranging from 12 to 23 feet. On the narrow part of the bed the shoal ridge along the eastern edge is very prominent. Except on the extreme northern portion, the bottom is very hard, consisting of shells for over 3 feet, which was as far as the probe could penetrate. An inconsiderable amount of sand and mud was found on the surface. On the northern portion the bottom is softer and the shell stratum thinner; mud sloughs are frequent, but where the groups of oysters were found the substratum was hard. The surrounding bottoms were—to the eastward mud and to the westward principally sand, though many mud holes and sloughs exist, especially on those parts contiguous to the bed. In this direction the oysters are scattered in groups and patches as well as singly, and the muddy bottoms were usually found in the vicinity of those groups. Between this bed and the Muscle Hole Bed the bottom is soft mud, and between the bed and Paul's Bed to the southward the bottom is hard sand.

The mature oysters were large, of good quality, and single; only a few clusters were found. On the northern portion were very few young, young growth, or drills, but a moderate amount of red and gray sponge. On the central portion, about one-third of the oysters were young growth, and a very fair number of young, with a few drills (*astyris*), and a small amount of red sponge were found.

No oysters were found on the soft bottoms east of the beds. Those scattered to the westward were large and of good quality. Very few young and fewer drills were found; where the groups were encountered in a few cases, a moderate number of the oysters were "young growth," but generally there was a marked absence of that class. Sponges were found on the sand in moderate quantity. The number of oysters to the square yard, the mean of fourteen observations, was 0.27. The number on the area occupied by scattered oysters, the mean of twelve observations, was 0.03.

*Paul's Bed.*—This bed lies on the western side of the channel, opposite the mouth of the Little Annemessex River. It is south of the Terrapin Sands and north of a bed called the Woman's Marsh, with which it is connected. It is similar to the latter bed, being broken in many places by mud and sand sloughs, and with the oysters growing in groups and patches. Its area is 765,000 square yards. The depth of water over the bed is from 14 to 16 feet. The bottom is generally of sand, but many mud sloughs were found. No specimens were obtained from this bed, but the oysters are probably similar to those found on the Woman's Marsh Bed, which will subsequently be described.

Between Paul's Bed and the Terrapin Sands, on the area covered by the broken lines, very few oysters are found, and on the eastern side of the channel, between Harris' Bed and the bed off Jane's Island Light-House, none at all, presumably on account of the character of the bottom, which is soft, shifting sand.

*Bed off Jane's Island Light-House.*—To the northward of the channel into the Little Annemessex River, and to the eastward of the channel of the Sound, there is a bed extending from the channels to and over the shoal about the light-house off Jane's Island. It comprises an area of 1,800,000 square yards, and is unbroken except about its southern and western boundaries, where it joins the channels. The depth of water is from 17 to 47 feet, the deep water being found on the western edge and the shoal water in the vicinity of the light-house and shoal extending from it to the westward. The oysters were unevenly distributed and were in largest numbers about the central portion of the bed in 3½ and 4 fathoms water. Along the edges of the bed where it is broken the oysters are scattered in groups and are in smaller numbers. The bottom is hard and of sand and shells, except near the channels, where some mud was found over the hard stratum. West of the bed there is soft mud and east of it hard sand. The oysters were single or in clusters of two or three, the single oyster of moderate size predominating. The young were no more evenly distributed than the mature oysters, large numbers existing on some parts of the bed, and very few on others. Those parts farthest from the channel appeared to have the largest proportion of young to mature oysters. A few sponges and some grass were found on the northern part of the bed.

*The Great Rock.*—On the eastern side of the Sound off Great Fog Island, and south of the channel into the Little Annemessex River, lies the largest oyster bed in either Tangier or Pocomoke Sound. It is called the "Great Rock," and comprises an area of 8,505,000 square yards. Its greatest length is 3¾ miles, and its greatest width, 1¼ miles. It is irregular in shape, and about two-thirds of its length to the southward it is divided into two portions. Originally these portions were widely separated, but, through the action of natural causes and the dredges, each portion has been extended until where the bottom was hard they have become united, and probably in the course of time the union will be more complete. The depth of the water over the bed can be seen by referring to the chart. The inner limit of the northern and larger bed is approximately indicated by the 3-fathom curve, and as no oysters were found in deeper water than 8 fathoms, the depth of water over the bed is, therefore, within those limits. Generally speaking, the deepest water is over the lower part of the larger portion. The inner limit of the smaller portion of the bed is not as well defined as that of the other, and some of the oysters on this area are found in 2 fathoms of water, and on and about the 2-fathom shoal off Great Fog Island. The muddy bottoms of the main channel lying in from 5 to 9 fathoms of water define the western limit of the bed, and a deep mud slough which separates it from the bed off Jane's Island Light forms the northern boundary.

The northern and western portions of the bed are somewhat broken, the oysters growing in groups, which decrease in size and number as the edge of the bed is approached. Similarly towards the eastern and southern limits the oysters begin to scatter in groups and singly, but the main bed may be considered solid, only a few mud sloughs and sand spaces of inconsiderable area existing in

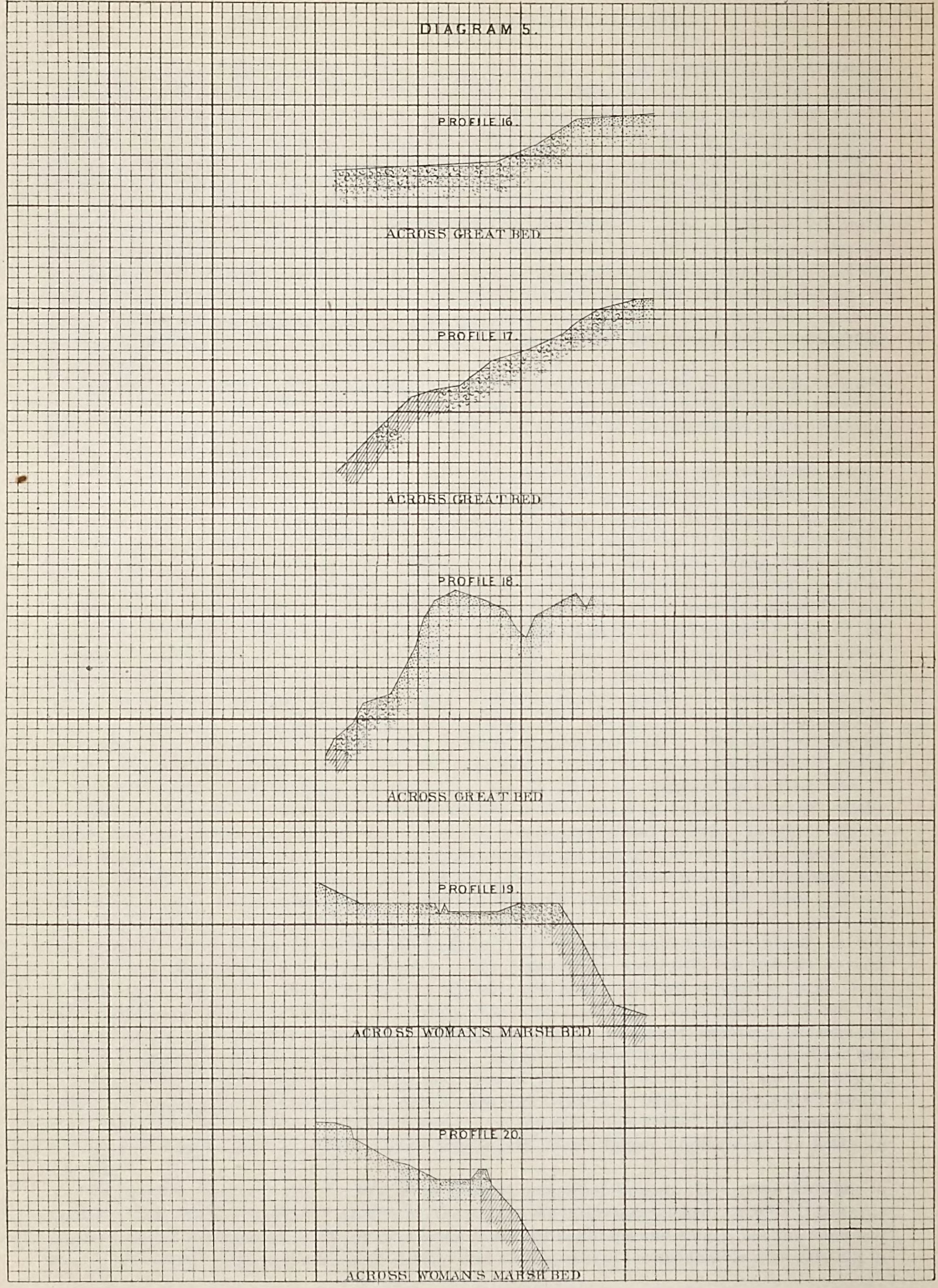


DIAGRAM 5.

PROFILE 16.
ACROSS GREAT BED
PROFILE 17.
ACROSS GREAT BED
PROFILE 18.
ACROSS GREAT BED
PROFILE 19.
ACROSS WOMAN'S MARSH BED
PROFILE 20.
ACROSS WOMAN'S MARSH BED

the interior. The oysters are distributed over the entire bed, but not evenly, the largest number being found in the vicinity of the dark line marked on the chart. The bottom is hard, of shells and sand; the oysters on the surface had a small amount of mud with them, the thickness of which was not uniform, but did not exceed a few inches. As the channel and northern boundary are approached the bottom becomes softer and more mud is found; on the eastern and southern portions of the bed the sand increased; north of the bed the bottom is mud, to the eastward and southward, hard sand, and to the westward, soft mud. On the bed itself the substratum of the bottom is probably hard sand, but owing to the great depth of water it was impossible definitely to ascertain the character of the substratum, except in a few isolated cases. The oysters found were single, of moderate size, and good quality; occasionally small clusters of two or three were discovered. Many young were found, but they were not evenly distributed, being in larger numbers about the central portion of the bed and decreasing as the edges were approached. On the southern and smaller portion the young were comparatively scarce. A moderate number of young had evidently been destroyed by the dredges, and large numbers were injured by drills; many drills were found attached to the oysters, and where the bottom was clean the drills were generally in direct proportion to the young, but where the red or gray sponge or grass existed there was a marked diminution of the number of young and a moderate diminution of the number of *astyris*. The sponge and grass were found in considerable quantities about the western and southwestern edges of the smaller portion, and to a less extent on the main bed. As the bottom became soft or muddy, both young oysters and *astyris* disappeared. Though the bed is so large and so favorably situated for production the oysters are not very plentiful, the number to the square yard, the mean of thirty-six observations made at different points, being but 0.16. The scattered oysters to the eastward are much larger and finer than those on the beds. They are singly on the sands, the distances separating them being proportional to the distance of the oysters from the main bed. To the southward and eastward the oysters are not so fine, especially those in the latter locality, where they grow on the edge of the mud, and have discolored shells and an unhealthy appearance. The number to the square yard, on the area occupied by scattered oysters, was 0.04.

*The Woman's Marsh Bed.*—This bed lies on the western side of the Sound, opposite the Great Rock, and is next to it in size, comprising an area of 6,975,000 square yards. It is irregular in shape, extends north and south along the edge of the channel for 4¾ miles, and is a little less than one-half mile broad. All parts of the bed are broken in many places, and this is especially the case about the middle portion. Large spaces of sand and smaller ones of mud are frequently met, and the oysters grow in groups of considerable size, separated by these spaces, except about the locality of the dark line drawn on the chart, where the bed is nearly unbroken.

The depth of water is from 13 to 22 feet; over the southern and middle parts of the bed the usual depth was about 19 feet, and on the northern portion about 14 feet was found. Generally speaking, the deeper water is near the channel, but on the extreme eastern edge of the bed the water suddenly shoals, usually to 16 or 17 feet, and sometimes to as little as 2 fathoms. Immediately to the westward the water deepens rapidly. The ridge is very narrow and on or near it the largest number of oysters were found; hence the dark line on the chart shows, approximately, its position. The shoal water is found on the western part of the bed, and the deep water over the soft bottoms and mud sloughs.

The oysters are spread over the entire area, with the largest number along the eastern edge of the bed, where the bottom is hard, though they are scattered over and about the mud and sand spaces. The bottom was hard, of shells and sand, except where the mud sloughs occurred, when the covering of shells was very light, and the mud underneath of considerable thickness. A little mud was found on the solid parts of the bed, the amount depending upon the distance from the channel or interior mud spaces. Very few observations were made of the substratum, but it is probably of sand, the bottom to the westward being of that description. East of the bed the bottom was soft mud. The oysters were large and single, occasionally of small clusters and of very good quality. Many young and many drills were attached to them and the old shells. The young were very unevenly distributed, the largest number being found about the locality indicated by the dark line on the chart and on the hard bottoms. The drills were similarly distributed, being usually in proportion to the young, though exceptions to this rule were more frequent than on the

Great Rock. Both young and *astyris* were found in greater numbers on the southern portion of the bed than on the northern. Along the eastern edge of the bed on the hard bottoms the red sponge was found, and a smaller amount on the central part; very little was found where the bottom was soft, and the number of young diminished where the amount of sponge was excessive. The number of oysters to the square yard, the mean of thirty-two observations made on different parts of the bed, is 0.24, which is somewhat larger than on the Great Rock, probably on account of shoaler water in which the dredging was done. The oysters scattered around the bed are similar to those on it, though they grow somewhat larger and have cleaner shells. To the westward the young were present in moderate numbers and with the usual proportion of *astyris*. But little sponge or grass was found in this direction, but to the southward both increased, and young and *astyris* disappeared. The number to the square yard, on the area occupied by scattered oysters, the mean of thirteen observations, was 0.06.

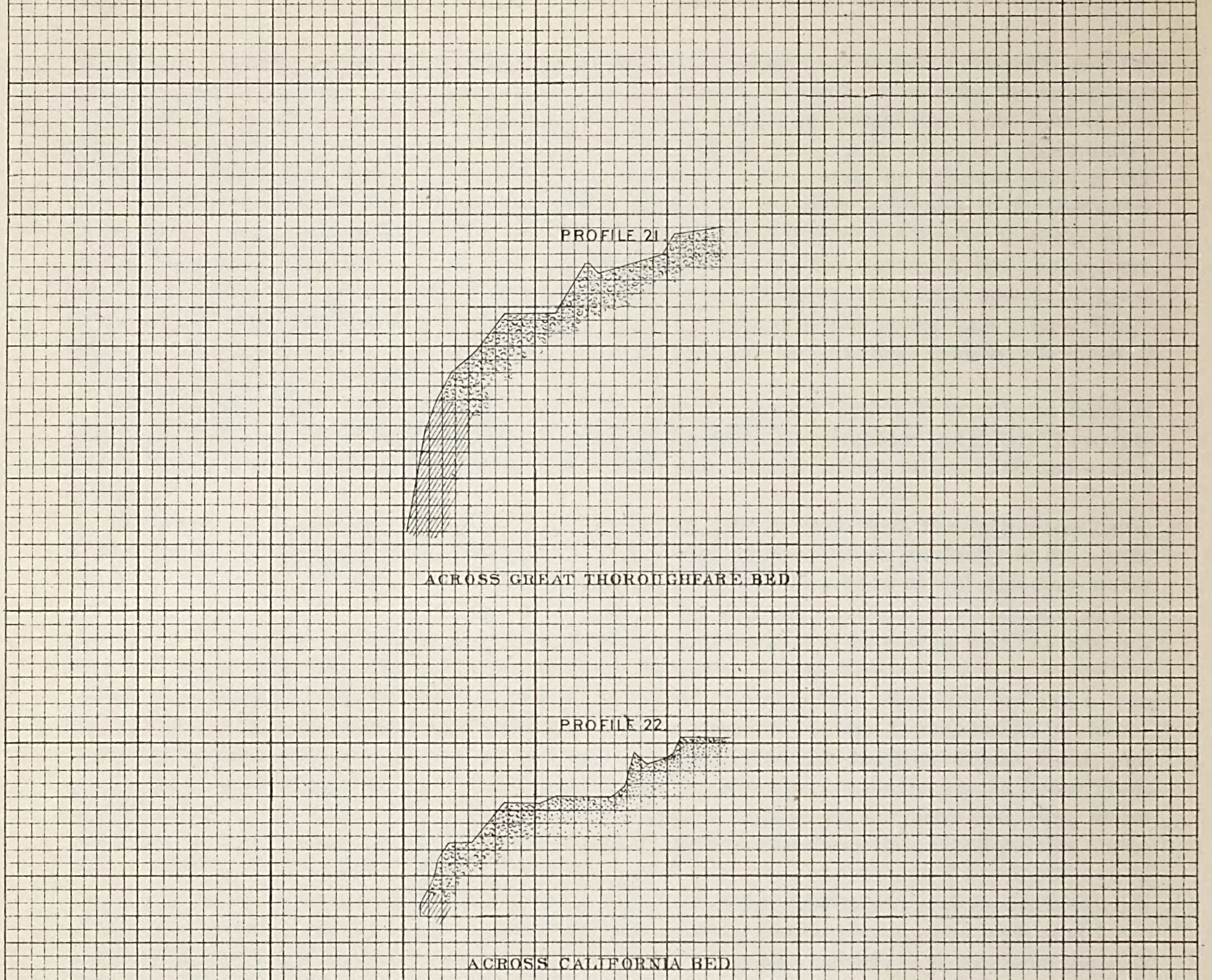
*Thoroughfare Beds.*—On the eastern side of the Sound, opposite Little Fox Island and south of the Great Rock, are two beds of moderate size, called the Little Thoroughfare and Great Thoroughfare. The area of the former is 720,000 square yards, and the area of the latter, 1,597,000 square yards.

The depth of water over the Little Thoroughfare is from 15 to 34 feet, the deep water being found over the western and southwestern portion and shoaling from thence gradually to the northward and eastward. Over the Great Thoroughfare the depth is from 16 to 54 feet, the deep water being found on the western and northwestern edge of the bed and shoaling to the southward and eastward. The space separating the beds is about one-fourth of a mile wide, and has over it a depth of water from 20 to 40 feet. The beds are unbroken except about the edges, where the oysters are scattered. On the western side of the Great Thoroughfare, where the bed extends to the soft muddy bottoms, the usual detachment of the oysters into groups is noticeable, but about the other boundaries, where the bottom is hard sand, the oysters are distributed more thinly and the breakage not distinguishable. The distribution of oysters was more even on the Great Thoroughfare than on the Little Thoroughfare bed, the largest number on the latter bed being found on the western part, while on the former the largest number was about the central portion. The bottom on both beds is hard, consisting of a stratum of shells and oysters 1 or 2 feet thick, over a stratum of sand. Very few observations of the character of the substratum were made, the depth of water being too great to permit it, but as the bottom as far as the channel was hard, and large numbers of shells and oysters were brought up from the western border, it is probable that the shell stratum continues as far as the muddy bottoms.

The oysters were of moderate size, usually single, but occasionally in small clusters. Large numbers of young were found on the extreme northern part of the Little Thoroughfare and on the central and western portions of the Great Thoroughfare bed, while very few young were found on the eastern part of the latter. Some of the young had been destroyed by dredges and a few by drills, though not many of the latter (*astyris*) were discovered. A small amount of sponge and grass was found about the edges of the beds. The number of oysters to the square yard, on the Little Thoroughfare, the mean of nine observations, was 0.14. On the Great Thoroughfare, the mean of ten observations was 0.11. On the area occupied by scattered oysters, the number to the square yard, the mean of seven observations, was 0.05.

*The California Bed.*—This bed lies on the eastern side of the channel, opposite the thoroughfare into Pocomoke Sound, and south of the Great Thoroughfare bed. It extends in a north and south direction about 3 miles, and is very irregular in shape. About the center it is divided by a mud slough one-eighth of a mile wide. The area of the bed is 3,915,000 square yards. Along the western part of the bed runs a narrow ridge, which is comparatively unbroken and appears to be the original of the bed defined on the chart. To the eastward of this ridge the stratum of oysters and shells is thinner, though the shells and oysters are spread quite evenly, diminishing in numbers as the edge of the bed is approached. West of the ridge and also in the vicinity of the dividing mud slough, the bed is broken into detached groups of oysters and shells. The depth of water is from 17 to 39 feet, the deepest water being found on the northwestern and western parts of the bed. Except about the western border, the bottom is hard. Only a few observations of the character of the bottom could be made, either on the bed or in its vicinity, the depth of water being

## DIAGRAM 6.


PROFILE 21.
ACROSS GREAT THOROUGHFARE BED.
PROFILE 22.
ACROSS CALIFORNIA BED.
PROFILE 23.
ACROSS CALIFORNIA BED.
PROFILE 24.
ACROSS JOHNSON'S BED.

too great. Such as were obtained showed a substratum of hard sand, and it is probable that the substratum is similar on all parts of the bed.

On the central portion of the bed the oysters were single, of moderate size, and fair quality, but not numerous. Very few young, very few *astyris*, and but little red or gray sponge were discovered. On the western part of the bed the oysters, though similar in character, were in greater numbers, young and old, and where the number of young increased, a proportional increase in the number of *astyris* was noticed. On the eastern part of the bed the number of oysters, young and *astyris*, considerably diminished. About the edges of the bed the grass, sponge, and sea-weed increased, and where this occurred a decrease in the number of young was noticed. The number of oysters to the square yard, the mean of thirty-six observations, was 0.21. On the area occupied by scattered oysters, the number to the square yard, the mean of eighteen observations, was 0.06. On account of the depth of water, and other unfavorable circumstances, both results must be regarded as a much rougher approximation to the real number than in the cases of the beds previously described.

*Johnson's Bed.*—This bed lies on the eastern side of the Sound, immediately to the westward of the 3-fathom shoal off Watt's Island Light-House. The bed is separated into two portions, of nearly equal area, by a dividing space of sand which extends north and south, following the general direction of the bed. Each portion is about one-eighth of a mile, and the northern and southern extremes are separated one mile and a quarter. The area of the bed is 1,395,000 square yards. The bed is unbroken, except about the edges, and the oysters exist on the entire area, though unevenly distributed, the larger number being found about the center of the bed. The bottom is comparatively regular, the depth of water being from 24 to 36 feet, the greater depths being on the western part and the least on the eastern part of the bed. On account of the depth of water and unfavorable nature of the weather during the examination of this bed no observations of the character of the bottom were made. The lead showed a hard surface stratum, except about the western edge, where mud was found. The oysters were large and single with many young and drills (*astyris*). Very little sponge was found on the bed, but on the shoal to the westward and between Johnson's and the California Beds there was a large amount of it. Very few oysters were found in this area. The number of oysters to the square yard, the mean of four observations, was 0.19.

East of Johnson's Bed is a small rock, called "Parker's Hill," which for want of time was neither surveyed nor examined. It is of little importance and seldom worked.

*Oak Hammock Rocks.*—These beds are situated on the western side of the Sound at the entrance to and in a large mud slough, which extends as far as Queen's Reach into the sand shoal surrounding Tangier Island. Each of the beds has a distinguishing name and is separated by mud sloughs from the others, but as the areas are small and the outlines of the rocks very indefinite I have included all of them under the name by which the assemblage is generally designated. The beds extend northwest and southeast about three-fourths of a mile, and the area is irregular in shape. The depth of water is from 9 to 24 feet, and the bottom is a stratum of shell, mud, and sand, over a stratum of mud. Underneath this mud, where it was not too thick for penetration, we found a hard stratum. The majority of the oysters were old, of small size, single, and in small clusters. Neither young nor drills (*astyris*) were found, and but a moderate amount of sponge. To the northward and westward of the beds the oysters are scattered in the mud in groups and patches. The total area of the bed is 600,000 square yards.

On the sand shoal between the Oak Hammock beds and the Woman's Marsh no oysters have ever been found.

## DENSITIES.

Specimens of the bottom water taken on each bed, at all stages of the tide, have been tested with the hydrometer and its readings reduced to a standard temperature of 60° Fahr. These results show a maximum density of the waters of Tangier Sound of 1.0164, which was found in the lower part, about the California Rock, at half flood-tide. The minimum density of 1.0111 was found in the upper part of Fishing Bay, with the tide three-quarters ebb. The following table shows the maximum and minimum density on each bed, with state of tide and remarks:

*Comparison of densities—Tangier.*

[The figures represent the excess of density over that of distilled water, which is represented as 1.000.]

| Bed. | Max. density. | Tide. | Remarks. | Diff. | Min. density. | Tide. | Remarks. |
|---|---|---|---|---|---|---|---|
| Fishing Bay | 1.0136 | High water | Southern part | .0025 | 1.0111 | ¼ and ¾ ebb | Extreme northern part. |
| Were Point | 1.0139 | ½ flood | In channel to Hooper's Straits | .0022 | 1.0117 | Low water |  |
| Shark's Fin | 1.0143 | High water | Edge of main channel | .0025 | 1.0118 | ¾ ebb | Middle of bed. |
| Nanticoke M. G | 1.0136 | High water | West of channel | .0017 | 1.0119 | ½ ebb | Middle of bed. |
| Clump Point | 1.0118 | ¾ flood | Only one specimen |  |  |  | No specimen. |
| Horsey's Bar<br>Tyler's Rock<br>Drumming Shoal | 1.0132 | ¼ ebb | Only one specimen | .0012 | 1.0120 | ½ flood | Only one specimen. |
| Grass Tangier | 1.0144 | ¼ flood | In the channel | .0024 | 1.0120 | Low water | Middle of bed. |
| *Turtle Egg Rock | 1.0120 | ¼ flood |  |  |  |  |  |
| Chain Shoal | 1.0145 | ¼ flood |  | .0022 | 1.0123 | ¾ flood |  |
| Mud Rock | 1.0144 | ¾ flood |  | .0008 | 1.0136 | ¾ ebb |  |
| Muscle Hole | 1.0157 | ¼ ebb |  | .0012 | 1.0145 | Low water |  |
| Piney Island Bar | 1.0150 | ½ ebb | South of beds | .0019 | 1.0131 | ½ ebb | Middle of bed. |
| Manokin River | 1.0152 | ¼ ebb | Lower beds | .0014 | 1.0128 | ½ ebb | Upper beds. |
| Big Annemessex | 1.0151 | High water | Western beds | .0007 | 1.0144 | ½ ebb | Eastern beds. |
| Harris Rock | 1.0153 | ¼ ebb | Southern beds | .0007 | 1.0146 | High water. |  |
| Terrapin Sands | 1.0159 | ¾ ebb | Strong southerly winds | .0015 | 1.0144 | ½ flood | Light southerly breezes. |
| Rock off Jane's Island | 1.0156 | ½ ebb |  | .0013 | 1.0143 | ¾ flood |  |
| Great Rock | 1.0159 | ¼ flood |  | .0011 | 1.0148 | High water. |  |
| Woman's Marsh | 1.0160 | ¾ ebb | Opposite opening between Tangier and Smith's Island. | .0016 | 1.0144 | ¾ flood |  |
| Little Thoroughfare | 1.0158 | ¾ ebb |  | .0009 | 1.0151 | ½ flood |  |
| Great Thoroughfare | 1.0157 | ½ flood, ¾ ebb |  | .0005 | 1.0152 | ½ flood |  |
| California | 1.0164 | ½ flood |  | .0012 | 1.0152 | ¾ flood |  |
| Johnson's Rock | 1.0161 | ½ flood |  | .0013 | 1.0148 | ½ ebb |  |
| Oak Hammock | 1.0160 | ¼ ebb |  | .0002 | 1.0158 | ½ ebb |  |

*All specimens taken on flood. This is minimum density.

By consulting the table it will be seen that the state of the tide has but little influence upon the density, though the depth of the water has, and the prevalence of strong winds may increase or diminish it. There is shown a gradual and constant increase of density as the southern portion of the Sound, where it opens upon the Chesapeake, is approached. There is also an increase of density when in the vicinity of the openings into the bay, and a decrease in the various rivers and off their mouths.

Though the density of the water increases, yet the difference between the maximum and minimum density steadily decreases to the southward, showing that the oysters on the northern beds are exposed to greater fluctuations of density, and probably salinity, than those on the beds to the southward.

There were no heavy rains during my stay in the Sounds, and the densities given therefore show only the condition of the water in that respect during dry weather. I was informed that there was a noticeable change in its character about the mouths of the tributaries of the Sounds after a heavy rainfall, and the effect upon the oysters was also perceivable.

The difference between the maximum and minimum density of the Sound amounts to 0.0053; but the difference between the maximum and minimum density on each bed will give a more correct idea of the changes to which the oysters are exposed. The greatest difference is 0.0025, which occurs on the Shark's Fin and Fishing Bay Beds, and the least difference on any of the main beds is 0.0009 on the Little Thoroughfare.

It would be perhaps still more correct to divide the Sound into several parts and consider the fluctuation of density over them, thereby assembling a larger number of observations. Throwing out the Fishing Bay beds, which by their position are removed to a great extent from the conditions affecting the other beds, and including all those south of Clay Island as far as Piney Island bar, where the influence of the Manokin and Annemessex Rivers would be felt, the difference of density amounts to 0.0028.

The difference of density over the beds south of Little Island and north of Little Annemessex River is 0.0031.

The difference of the beds south of Jane's Island Light is 0.0020.

These differences show that the greatest fluctuation is over the beds in the middle of the Sound, and is probably due to the influence of the Big Annemessex and Manokin Rivers and the waters entering by Kedge's Strait.

Throughout the Sound there is a marked difference between the densities of the water taken about the latter part of August and the first part of September and those taken in October. This difference is given in the following table:

| Bed. | Date first observation. | Date second observation. | Difference in density. | Bed. | Date first observation. | Date second observation. | Difference in density. |
|---|---|---|---|---|---|---|---|
| Flushing Bay | Aug. 24 | Oct. 5 | .0018 | Harris's Rock | Aug. 29 | Oct. 1 | .0005 |
| Were Point | Aug. 24 | Oct. 5 | .0014 | Great Rock | Aug. 30 | Sept. 28 | .0007 |
| Nanticoke Middle Ground | Aug. 26 | Oct. 5 | .0014 | Woman's Marsh | Aug. 30 | Sept. 23 | .0008 |
| Bed north of Turtle Egg Island | Aug. 26 | Oct. 4 | .0016 | Great Thoroughfare | Sept. 5 | Sept. 28 | .0007 |
| Chain Shoal | Aug. 27 | Oct. 8 | .0011 | California | Sept. 6 | Sept. 26 | .0009 |
| Piney Island Bar | Aug. 28 | Oct. 4 | .0010 | Johnson's Rock | Sept. 6 | Sept, 20 | .0010 |
| Manokin Bed | Aug. 27 | Sept. 30 | .0017 | | | | |

The earlier observations show the least density.

It will be seen by the table that the observations were made at from two weeks to six weeks apart; that, generally speaking, the amount of difference in the densities increases with the interval between the observations, and that the northern beds and those in the rivers are exposed to greater fluctuations of density than the neighboring ones in the Sound. If the change of density over the beds, as shown by these tables, represents with approximate accuracy the change of salinity of the water, the fluctuation is too slight to seriously affect the beds or oysters; but if the slightness of the change is due to organic matter held in solution by the waters of the ebb tide, which would replace the salt of the flood, there may be a much greater difference in the salinity of the flood and ebb than has been indicated by the hydrometer.

### CURRENTS.

The general set of the currents in the Sound is north and south, following the main channel and diverging slightly about the mouths of the tributaries and straits.

In the following statements regarding the currents the influence of the wind has not been eliminated, and accounts for many irregularities, both of velocity and direction, and about slack-water, especially of the windward tides, this influence was most apparent.

In Fishing Bay the currents follow the general bend of the shores and channel, setting over the lower portion, on the flood, to the northward; over the middle portion to the northward and westward, as far as Fishing Point, and above that point, and over the upper part of the bay, setting to the northward and eastward. The maximum observed velocity of the flood current was 0.38 of a mile per hour. The ebb in each portion of the bay sets in an opposite direction to the flood.

The currents about the northern part of the Were Point bed were measured during and after strong northeast winds, which accounts for the set to the southward and westward, and also for the slight velocity of the ebb, which was only 0.15 of a mile per hour, the northeast wind having lasted for two days and having driven a good deal of the water out of Fishing Bay.

Over the Shark's Fin the flood current sets to the northward and the ebb to the southward and eastward, most of the latter apparently coming from Hooper's Straits. Its maximum velocity was 0.4 of a mile per hour. The observations of the strength of the flood current made on this bed were too much influenced by the wind to be considered reliable, but the velocity immediately south of the bed was 0.5 of a mile per hour.

The currents of the Nanticoke Channel and over the adjacent beds set to the northward and eastward on the flood, following the bend of the channel, with a maximum velocity of 0.6 of a mile per hour. The ebb over the major portion of the Middle Ground sets to the southward, with a velocity of 0.3 to 0.4 of a mile per hour on the first quarter, until it meets the current of the Wicomico, when it turns to the westward. A strong current sets in and out of Rock Creek; over the Drumming Shoal and Cedar Rocks the current sets NNE. on the flood, with a velocity of 0.4 of a mile per hour, and SSW. on the ebb tide, with a velocity of 0.6 of a mile per hour.

Over the beds south of the Shark's Fin and Cedar Rock, and north of Piney Island bar and Kedge's Straits, the general set of the flood is to the northward, with an inclination towards Holland's Straits when about Turtle Egg Island, and tending to the northward and westward off the Little Thoroughfare. The general set of the ebb while in the channel is to the southward, but on the Turtle Egg Island, Mud and Muscle Hole Beds the set is to the southward and eastward. The strength of these and all currents in the Sound is much influenced by the winds that have prevailed during the immediately preceding days, and which it was impossible to eliminate in the space of time covered by this investigation. Over the western beds, above Kedge's Straits, the maximum observed velocity of the flood was 0.8 of a mile per hour, and a mean of all the velocities of the flood current was 0.4 of a mile per hour. The maximum observed velocity of the ebb current was 1.0 mile per hour, and the mean of all velocities of the ebb was 0.3 of a mile per hour.

Over the Chain Shoal the maximum velocity of the flood was 0.37 and the mean velocity was 0.3 of a mile per hour. The maximum velocity of the ebb was 1.0 mile and the mean velocity 0.5 of a mile per hour.

The flood current over Piney Island bar sets NNW., or about in general line with the Sound at that point. Its velocity on the third quarter, during and after northerly breezes, was 0.1 of a mile an hour, and probably it is seldom less than that. The ebb current over the northern part of the bed sets SSE., but tends to the southward over the southern part. The maximum velocity of the ebb during and after northerly breezes was 1 mile per hour and the mean of all observations, taken under similar circumstances, gives a velocity of 0.4 of a mile per hour.

In the Manokin River the current follows the general trend of the channel, the flood setting to the northward until above Hazzard's Point, and then to the northward and eastward. The ebb sets southwest, and, when it strikes the shoal off Piney Island, curves somewhat to the southward. The currents were measured during light or gentle northeasterly breezes. The maximum velocity of the flood was 0.4 of a mile per hour and the mean of all the velocities of the flood 0.2 of a mile per hour. The maximum velocity of the ebb was 0.5 of a mile per hour and the mean velocity 0.2 of a mile per hour.

In the Big Annemessex River the current sets to the eastward on the flood tide and to the westward on the ebb, curving to the southward on the latter as it approaches the mouth of the river. The maximum velocity of the flood current was 0.4 and the mean velocity 0.25 of a mile per hour. Of the ebb the maximum velocity was 0.5 and the mean velocity 0.33 of a mile per hour.

The flood current sets over Harris Rock to the northward with a maximum velocity of 0.33 and a mean velocity of 0.2 of a mile per hour. The ebb, being somewhat influenced by the current out of the Annemessex and the sweep of the main current of the Sound, sets to the southward and westward, with a mean velocity of 0.2 of a mile per hour. The maximum velocity observed was but a slight increase of the mean.

Over the Terrapin Sands the flood sets northwest, with a maximum velocity of 0.9 and a mean velocity of 0.7 of a mile per hour. The ebb sets southeast until near the buoy marking the shoal, where it turns to the southward. Its maximum velocity was 1 mile and its mean velocity 0.9 of a mile per hour. The currents over the Terrapin Sands were measured during spring tides, and after light breezes and calms had prevailed for several days.

Over the Woman's Marsh Rocks the flood sets about NNW. until in the vicinity of Horse Hammock, where it turns to the northward and eastward. The ebb sets SSW. over the upper part of the bed, and to the southward and eastward over the lower. There is a strong set in and out of the opening between Tangier and Smith's Islands. The maximum velocity of the flood was 0.7 and the mean velocity 0.6 of a mile per hour. The velocity of the ebb was, maximum 0.8 and mean 0.4 of a mile per hour. These currents were also measured during spring tides. Along the eastern side of the Sound, below Jane's Island Light and over the several beds located on the eastern edge of the channel, the general set of the current is to the northward on the flood and to the southward on the ebb. The flood sets a little to the eastward or westward of north as the channel changes in direction, and about the northern part of the Great Rock sets strongly to the northward and eastward into the Little Annemessex. The ebb current out of that river forms a strong tide rip where it joins the main current due east of Jane's Island Light and on the northern part of the bed off that light. The general set of the ebb is the reverse of that of the flood, and both currents follow the trend of the channel.

Through the Thoroughfare, opposite the California Rock, the flood sets east into Pocomoke on the first three quarters, and west on the last quarter. On the ebb the set is westward on the first three and eastward on the last quarter, and this irregularity is communicated to some extent to the waters over the California Rock.

The maximum velocity of the flood current on the eastern side of the Sound, below the Little Annemessex, was 0.3 and the mean velocity was 0.2 of a mile per hour. The maximum of the ebb was 0.8 and the mean 0.7 of a mile per hour. Most of these currents were measured during northerly winds, which would increase the ebb and diminish the flood currents, and probably they are more equal than the observations show them to be.

Over the Oak Hammock Rocks the flood sets to the northward and westward, and the ebb to the southward and eastward, with a velocity of from 0.1 to 0.2 of a mile per hour.

Reviewing the currents, it will be seen that the strongest on both tides were those over Terrapin Sands during the spring tides, their velocity being about one mile per hour. As the observations over the Sound were made during various states of the weather and of tide, the highest velocity obtained is probably as great as ever sets over any of the beds.

The velocity, except within wide limits, however, is not so important to the oysters as the direction of the current, and that has been ascertained with, I hope, sufficient exactness to assist, so far as it can, in the study of the beds.

## DEPOSIT.

It would require a much longer period of observation than was at our disposal, and a much more extensive and careful investigation of the character of the water and bottom of the Sound than I was enabled to make, to allow me to speak with authority or exactness upon this subject; but from the information collected from the most intelligent of the oystermen whose experience on the beds was considerable, I am of the opinion that there is little or no systematic deposit going on upon any of the beds of the main Sound. There must be some sediment contained in the waters of the rivers and creeks, but it appears to be deposited on those beds near their mouths. In the upper part of Fishing Bay, on the Clump Point Rocks, Middle Ground of the Nanticoke, in the Manokin and Big Annemessex Rivers, there is a larger amount of mud in the surface and underneath than elsewhere in the Sound. Those beds lying in deep water are particularly free from an undue proportion of mud on the bottom, the shoalest beds having the thickest mud covering.

If there was a constant and increasing deposit upon the beds they would long ago have disappeared, or at least have become of much smaller area, but the reverse is the case, the beds increasing in area constantly.

They are, however, exposed to one species of deposit which is very injurious. Heavy gales occurring in winter and summer frequently tear up the large quantities of grass, sea-weed, and sponge on the sand shoals about the Sound and deposit it upon the beds. If this occurs in summer, when there are a smaller number of dredgers at work, the effect is very injurious, the "cultch" being covered, and the young, if spawned, smothered by the grass, weeds, sand, and mud which it collects. The California Rock, Piney Island bar, and Manokin beds are those most subject to this evil.

The gales also have the effect of covering the scattered oysters on the leeward sands, which process is called "sanding," and, from what I could learn, appears to be a very injurious one. The oysters are buried, and the bottom becomes smooth and hard. Where at least thirty bushels of oysters could be taken previous to a gale, not one oyster could be found subsequent to it. The winter gales have the greatest effect, owing probably to their greater severity, and direction, which is from the northward and westward. The "sand" oysters are found in largest numbers on the eastern shores of the Sound, and about Kedge's and Hooper's Straits; consequently they would feel a northwesterly gale much more than one from the opposite direction. They are said not to recover from the "sanding" for several months, and upon their reappearance are noticeable on account of the whiteness of their shells. Though there were several very heavy blows while we were in the Sound, they were not of sufficient severity to produce the effect spoken of, and if they had been I should not have been able to detect it, on account of the shallowness of the water in which the scattered oysters lie, which prevented the schooner's dredging for them.

### EFFECT OF GALES AND ICE.

As there was no opportunity for me to investigate this question in person, the examination of the beds having been accomplished during the summer and autumn months, the following information is derived from the queries put to the oystermen and persons inhabiting the shores of the Sound. The heaviest gales during the winter season are from the northward and westward; during the summer season, from the southward, and southward and eastward. The gales from the eastward, southward and eastward, and southward, cause an increase of depth over all the beds, amounting sometimes to 2 feet, and the northerly and westerly gales a contrary effect, but not sufficient to leave any of the natural beds uncovered, except one or two small patches in Fishing Bay. Gales from any direction cut away considerably the leeward shores and points, especially when they are of a sandy nature. Those parts of the Sound suffering most in this respect are Bishop's Head, Haines' Point, and Diel's Island, Little Island, the shores about and near Jane's Island Great Fox Island, the shores about Horse Hammock, and the southern part of Watts and Tangier Islands. Cod Harbor, in Tangier Island, is said to be filling up with the washings of the sand-spit to the southward.

Though it is said the amount washed away from these points is considerable, no additional deposit was ever noticed on the beds, nor did the gales appear to affect them in any way other than has already been described, except in conjunction with the ice in the winter.

Ice never rests upon the main beds except in a few isolated cases where there happens to be a very shoal spot on the bed; as, for instance, occasionally the ice will ground on some of the small rocks in Fishing Bay and once in a while on the Woman's Marsh, but not often. The injury done the oysters by the grounding depends upon the length of time the oysters are in contact with the ice. If it only touches in a few places not much harm is done; indeed, it is supposed to protect the majority on the bed by covering them, but where there is a contact all over the "rock," the oysters are killed in a short space of time. The number of points in the Sound where it is possible for the ice to rest is inconsiderable, and not many of the animals are destroyed by the grounding of the ice, though they are affected seriously by its long continued presence.

The winter gales break up the ice fields and pile them up in immense masses on the leeward shores and over the adjacent beds. The Shark's Fin Bed suffers particularly in this respect. A good deal of damage is done to the shores by the ice, and the oysters feel the effect, showing it by becoming what is called "winter-killed," or poor and weak, having a slimy, sickly appearance when opened. Many die on the beds from this cause, and after the disappearance of the ice ten days or two weeks must elapse before they are fit for marketable purposes. Ordinary cold weather and a moderate amount of ice is said to improve the fishing, the oysters appearing to be drawn more to the surface of the bed and the shells to sink more toward the bottom. My informants said this effect was quite noticeable.

No one that I was able to interrogate had ever seen an oyster frozen *in the water*, and the impression was that so long as the oysters were covered they would recover from any ill effects of ice or ordinary cold weather.

## POCOMOKE SOUND.

Pocomoke Sound extends from Watts' Island in a north-northeasterly direction 12½ miles.

The main channel is narrow with a varying depth of water, the main body of the Sound being covered by shoals with from 7 to 18 feet of water over them. Long sand-spits make off from most of the points and islands and separate the channels into the different creeks from each other. The Sound is about 9½ miles broad from shore to shore about its middle, but the channel occupies only 1¼ miles of this space.

The change of depth is gradual, except between Watts' and Beach Islands, near the southern extremity of the Sound, where the change from deep to shoal water is sudden. About the upper and northeastern portion the depth is more uniform, the deep channel shoaling to about 12 feet, and that depth being but slightly diminished close to the shores.

The beds do not, as in Tangier Sound, cover the shoals on each side of the channel, the majority being found on the eastern side, and only two beds to the westward of that part of the channel where the water is deeper than three or four fathoms.

The total area covered by oysters, to a greater or lesser extent, in this Sound is 34.12 square nautical miles. This area is that inclosed on the chart by the boundaries of scattered oysters, and is but approximate, as previously explained. The solid beds, comprising all parts of the Sound where oysters were found in a greater number than 0.1 to the square yard, or where the bed was found to be to all intents solid "oyster-rock," or comparatively unbroken, embrace a total area of 4.52 square nautical miles. The groups or rocks are not always contiguous, being frequently separated by the channels into the different creeks and rivers and by mud sloughs and spaces, and in only one case have the beds extended across a channel, and peculiar circumstances account for that exception. Generally speaking, they will be found to lie on each side of the main channel in the Sound and on each side of the channels into the rivers. Taking them in order from the mouth of the Pocomoke River to the entrance of the Sound, there are seventeen of a sufficient size to justify a separate consideration and name; and I have called them by the names given by the local oystermen to the solid "oyster-rock," which was probably the origin of the bed.

They are: The Old Rocks and New Plantation Rocks, Buoy Rock, Potter's Rock, Slatestone Flat Rock, Dog Fish Bed, Drum Bay Point Bed, Trevise's Bed, Shell Bed, Buoy Spit Bed, Muddy Marsh Bed, Bird Bed, Hern Island Bed, Beach Island Bed, Parker's Bed, and Brig Bed.

In considering and describing the beds I shall separate the first ten from the others, and, as they are subjected to very similar conditions of bottom, current, and density of water, shall treat them under one head, as the Pocomoke beds.

## SCATTERED OYSTERS IN POCOMOKE SOUND.

The area covered by scattered oysters is determined only approximately, it being very difficult to accurately define the limits. Generally speaking, the one-fathom curve will nearly mark the inshore limit, while the soft muddy bottom of the main channel will define the outer one. The depth of water over the scattered oysters and the character of the bottom can be ascertained by reference to the chart. No oysters were found in the deep channels nor on the shoal sand-spits.

The oysters are scattered singly and in groups, but usually grow singly, though numbers of small beds of a few hundred yards area are included within the limits of scattered oysters. In the vicinity of the Messongo and Guilford Creeks the oysters seem to be scattered in that manner, the spaces between the groups being proportional to their sizes. Very few oysters were found along the edge of the shoal on the western side of the channel south of the Muddy Marsh. In the channel itself no oysters were found. Opposite Beach Island, in from thirteen to fourteen fathoms, a few clams and shells were brought up. In this case, however, the bottom was of hard sand. The area covered, to a greater or less extent, by the scattered oysters comprises 122,117,000 square yards, or 29.60 square nautical miles. The number of oysters over this area, as nearly as I could ascertain, was about 0.12 to the square yard.

*Pocomoke Beds.*—Across the mouth of the Pocomoke River lie the "Old Rocks," comprising an area of 1,057,000 square yards, and marking the limit to which the oysters of the Sound extend, only few small rocks being found in the river. Below the "Old Rocks," on the western side of the channel, are the Buoy Bed, comprising three "rocks" and 967,000 square yards; Potter's Bed, of seven "rocks" and 900,000 square yards; Dog Fish Bed, of 720,000 square yards; Flat Bed, of 742,000 square yards, and Trevise's Bed, of 697,000 square yards.

On the southern side of the channel, and extending from it to the sands, are the Old Plantation Bed, of 180,000 square yards; the Slatestone Bed, of 967,000 square yards; the Drum Bay Point Bed, of 337,000 square yards, and the Shell Bed, comprising five "rocks" and an area of 1,102,000 square yards.

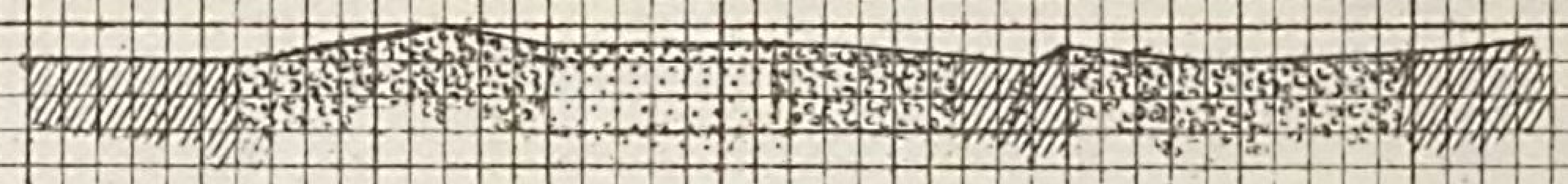
The depth of water over the beds can be seen and studied by referring to the chart. The average depth is from 8 to 12 feet at low and from 11 to 15 feet at high water, the deeper water being found near the channel and over the mud sloughs. Of the different beds the "Old Rocks," New Plantation, and Buoy are in the shoalest water, and the Shell Bed in the deepest. The channel has 27 feet off the Shell Bed, and shoals gradually to 10 and 11 feet off the Buoy Bed. None of the beds are solid or unbroken; those approximating to that condition are the "Old Rocks," New Plantation, Buoy, and Slatestone Beds. The majority of the beds have been cut up by the dredges or mud sloughs into small groups and ridges, with oysters scattered between them. The divisions, however, are too small to be shown on the chart.

The bottom generally consists of mud, and the stratum is both softer and thicker in the vicinity of the channel than elsewhere. On the beds remote from the channel hard bottom was occasionally found, and near the one-fathom curve sand and gravel; the last character of bottom was sometimes found in deep water, but not frequently, except about Trevise's Bed and near the sand shoal, to the southward and westward of Ape's Hole Creek. Between that creek and Meremscot Creek, to the eastward, the bottom is a mixture of sand and clay, and the locality is therefore a favorite planting ground, as is Ape's Hole Creek and the light above the "Old Rocks." On the Old Rocks we found the surface stratum of shells, oysters, and mud to be about one foot thick, and the substratum of soft sand or mud. In the vicinity of the bed the bottom is similar, except that the substratum is of shell. On the New Plantation Bed the surface stratum was of sand and shell, 3 feet in thickness, and the substratum hard sand. The Buoy Bed has a light covering of mud and fine sand on the shells and oysters, and a substratum of hard sand and shell. In the vicinity of the bed the bottom is soft mud. On Potter's Bed the surface stratum was of sand and shell, 1 foot thick, over a stratum of soft mud. In one case on the "rock" most remote from the channel the substratum was hard sand. Within the area north of Potter's Bed, occupied by scattered oysters, the bottom, with one exception, was of mud over a stratum of hard sand. On the Slatestone Bed the surface stratum is of mud and shells, from 1 to 5 feet in thickness, over a stratum of sand, or sand and clay. On the Dog Fish and Flat Beds we found a surface stratum of sand, mud, shells, and oysters 2 or 3 feet thick, and underneath that a hard stratum. About these two beds there are several places where the substratum was a mixture of sand and clay, similar to the bottom of the planting grounds. About and inshore of the Drum Bay Point Bed the bottom was of sand and gravel on the surface, with clay or sand and gravel underneath. The probe was not used on this bed nor on Trevise's Bed, but about the latter the bottom is of soft sand for a few feet and then hard sand. South of Trevise's Bed, near the channel, the bottom is of mud. The Shell Bed derives its name from the character of its bottom, which consists of a stratum of shells about 1½ feet thick, over a stratum of mud of from 1 to 4 feet in thickness, after which the bottom appears to be hard. In the vicinity of the bed the bottom is of sand, which becomes harder as the distance from the bed increases and the water shoals. In the channel the bottom is soft mud, and no oysters were found in it.

Within the lines defining the limits of the scattered oysters the animals are distributed, but very unevenly so. Even on the beds the distribution is by no means regular, or likely to become so, the production and growth of the oysters varying with the locality, and the size, contour, and character of each bed continually changing from the action of natural causes and the constant fishing. Throughout the area assigned to scattered oysters, many small lumps and patches may be found; but generally the oysters are scattered in small clusters or singly, and those on the beds are of the same general character, being small, single, or in clusters of two or three, and without parasites or parasitic attachments. There was a remarkable absence of young oysters of less than six months' growth, even, as in the case of the Shell Bed, where the bottom was clean and shelly,

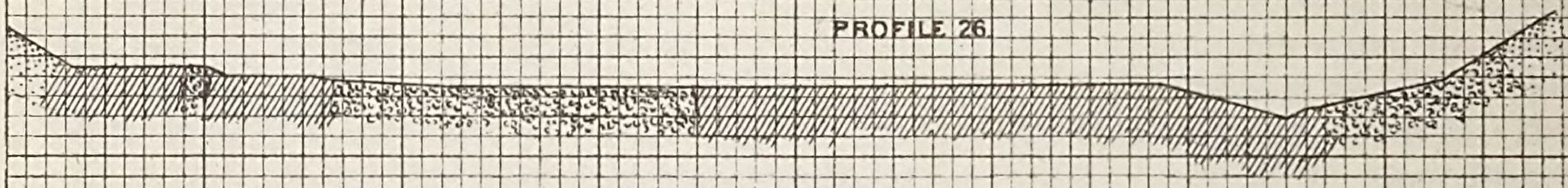
## DIAGRAM 7.

PROFILE 25.



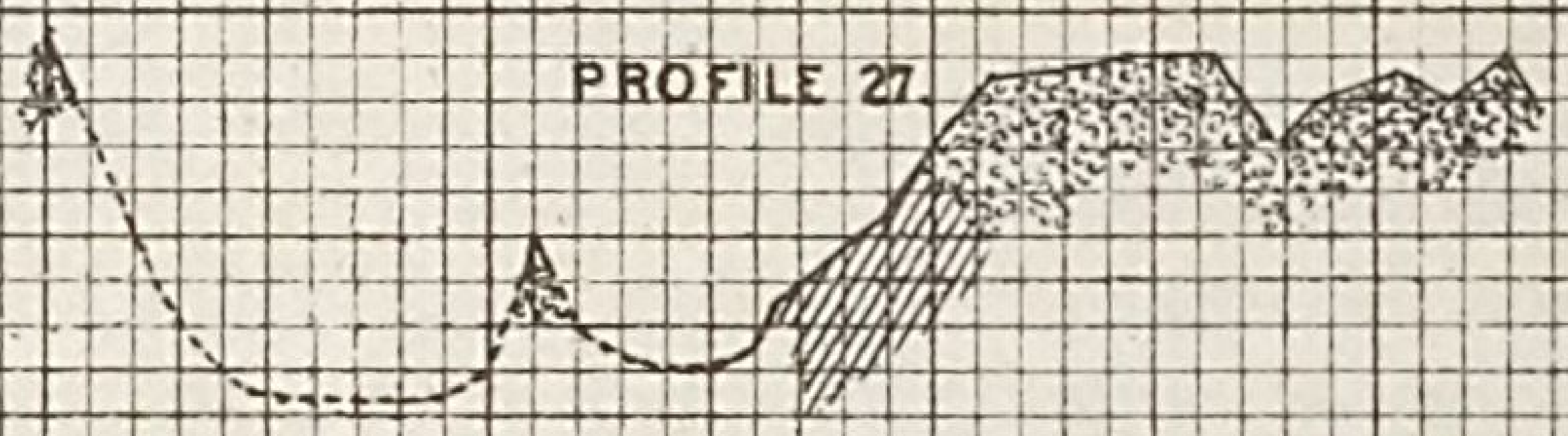
ACROSS POTTERS' BED

PROFILE 26.



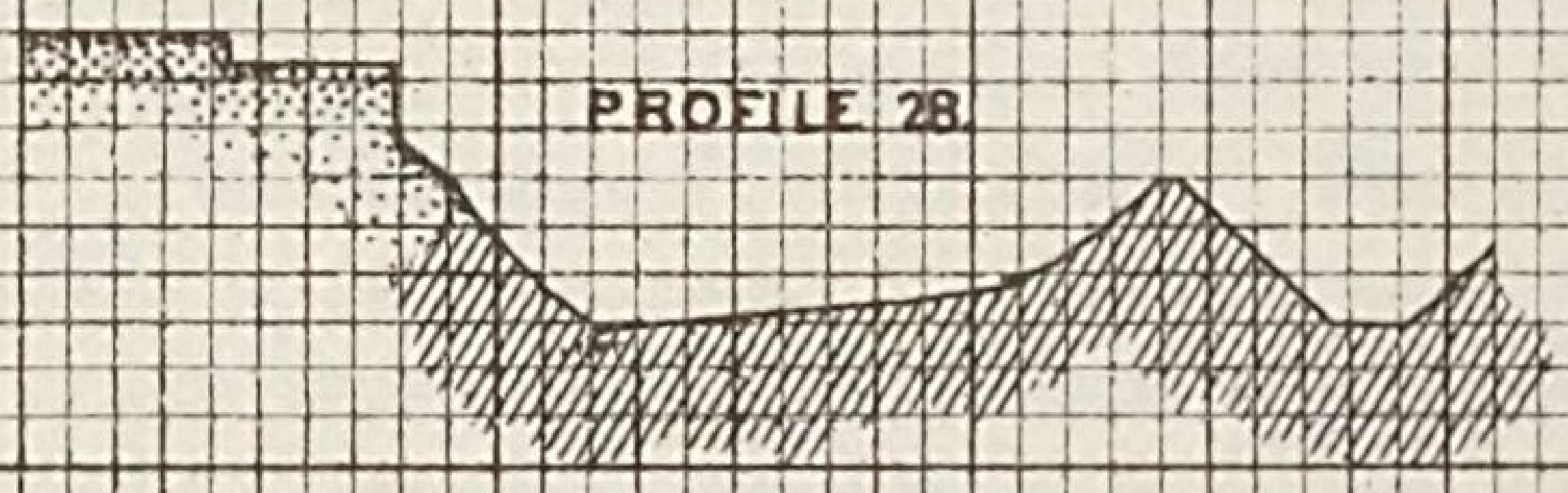
ACROSS UPPER PART POCOMOKE SOUND

PROFILE 27.



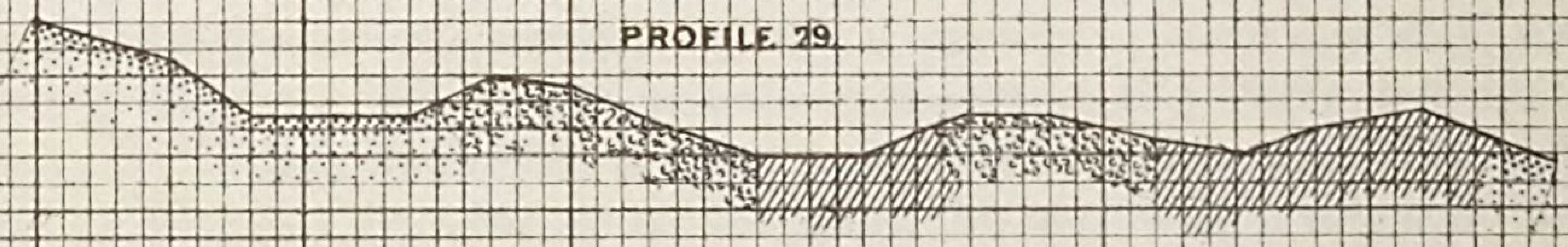
ACROSS SHELL BED

PROFILE 28.



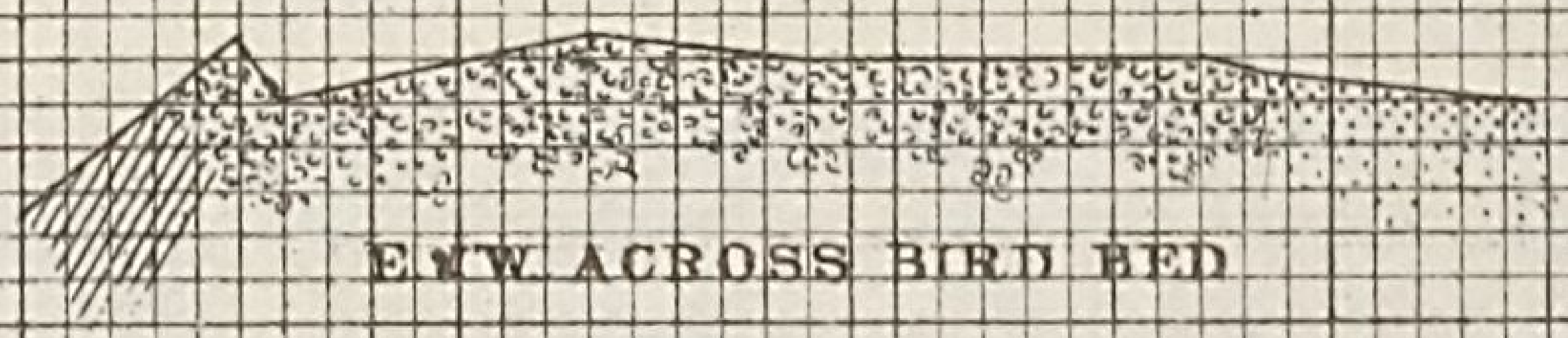
ACROSS BUOY SPIT & MUDDY MARSH

PROFILE 29.



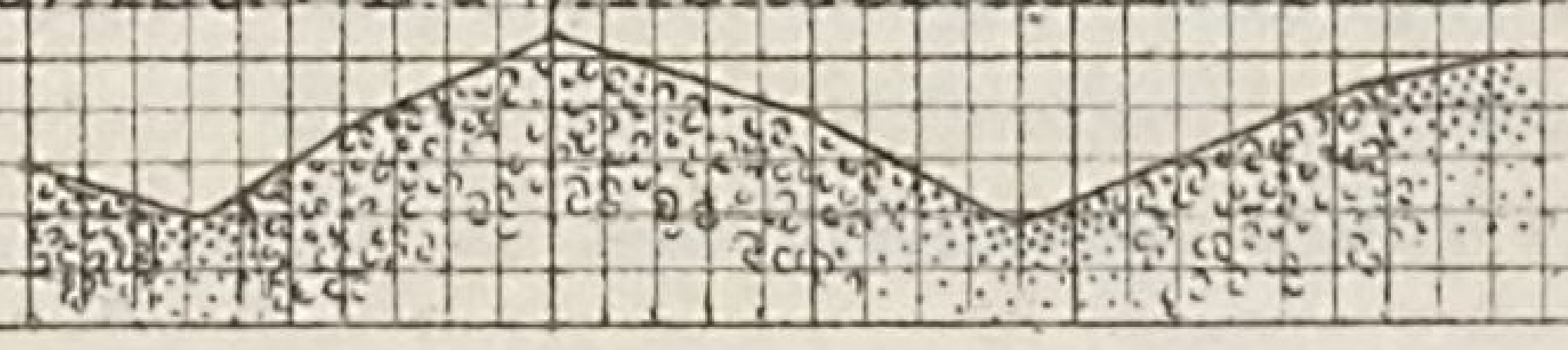
N. & S. ACROSS BIRD BED & HERN ISLAND BED

PROFILE 30.



E. & W. ACROSS BIRD BED

PROFILE 31 : E. & W. ACROSS HERN ISLAND BED



and apparently in good condition for attachment. Generally the mature oysters were scarce, though many shells were found, and on the Shell Bed the number to the square yard was as small as 0.015, though great quantities of broken shells were brought up. The Slatestone and Drum Bay Point Beds appeared to be in best condition, so far as to the number of oysters.

*Buoy Spit Bed.*—This bed lies on the eastern side of the channel, southwest of the Shell Bed and opposite the Muddy Marsh Bed. Its area is 427,000 square yards. It extends NNW. and SSE. five-eighths of a mile, and has an average breadth of one-quarter mile. The depth of water over it is from 14 to 19 feet, the shoal water being found on the southern part of the bed and the deep water on the northern part, and near the channel. The bed is comparatively unbroken, except about the edges, where the oysters grow in groups separated by mud sloughs. Apparently the bed is very old, the stratum of shells being very thick. The oysters are evenly distributed over the entire area. The bottom consists of a stratum of shells, oysters, and mud, about 3 feet thick, over a stratum of hard sand and shell; on the southern part of the bed the substratum is mud. In the vicinity of the bed the bottom is soft sand or mud, the latter being found in the channel. The oysters were single, with very few young attached; a moderate amount of red sponge was found. No oysters existed in the channel. Those scattered near the bed were to the eastward. They were similar in character to those on the bed, but a larger number of young were found, and about one-third of them had been injured by the drills.

*Muddy Marsh Bed.*—This bed is on the western side of the channel, opposite the Buoy Spit Bed, and comprises an area of 1,912,000 square yards. The main bed is long and narrow, extending 2½ miles along the edge of the channel, and being on an average about one-quarter of a mile broad. One-half mile to the northward of the main bed are two detached "rocks," whose area has been included in that just given. The depth of water over the bed, as will be seen by the chart, is from 11 to 17 feet; the small "rocks" have from 13 to 14 feet over them. The shoalest water found was about the central portion of the principal bed, and the ridge marks, approximately, the original oyster "rock." From this ridge the water deepens slightly to the westward and considerably to the eastward. The bed is comparatively solid, having few mud or sand sloughs in it; about the shoal ridge it is entirely unbroken. The oysters are spread unevenly over the entire area, the smallest number being found on the shoal, unbroken, central part, and the largest number about the extreme ends of the bed, where the water was deeper and the bottom softer. On the small beds to the northward the oysters were scarce, and many clams were found. The bottom on the two detached "rocks" consists of a stratum of shells and mud over a stratum of mud. To the southward, and between them and the main bed, the bottom is of hard sand and broken shells. Where the beds approach the channel the bottom is softer, and in the channel only soft mud is found. A few mud sloughs and mud patches were discovered at some distance from the channel, but generally the surrounding bottoms are hard. On the main bed a very thick and hard stratum of shells, with a little sand on the surface, composes the bottom. We could drive the probe down some 2 or 3 feet, but did not in any case penetrate the shell stratum, except on the southern portion, where the bottom is neither so hard nor so shelly as about the center of the bed. South and west of the bed the bottom is sandy, and hardens as the water shoals. A few mud sloughs were found along the western edge of the bed, but it is noticeable that on the principal part of the bed there was little or no mud, and that the bottom was fairly clean. The oysters on the bed and from its vicinity were of medium size and fair quality, single, and very scarce. Very few young, no young growth nor drills, and no sponge, grass, or parasitic attachments of any kind were found, but an immense amount of broken shell and other *débris* was brought up by each haul of the dredge. On one occasion the dredge filled in three minutes; shells and one oyster resulted. A similar haul produced a dredge full of shells and five oysters. As the dredge held about two bushels, the percentage of *débris* is thus shown to be enormous. The hauls were made on the shoal, solid portion of the bed, where, according to most experience, the oysters should have been most numerous. The number of oysters to the square yard, from observations in these places, was 0.40.

*The Bird Bed.*—This bed lies on the eastern side of the main channel and across the channel into Messongo Creek. It is irregular in shape, and is the largest bed in Pocomoke Sound, having an area of 3,285,000 square yards. The southern extremity joins the Hern Island Bed, thus practically making the two beds one; but as the oysters were not very thick in the channel into Guilford Creek, the original dividing space, and as the two beds still retain their original names, I have considered them separately. The depth of water over the Bird Bed is from 14 to 24 feet, the deep water being found near the channel and the shoal near the sand spits. The bed is unbroken, except about the edges; that portion indicated on the chart by the dark line is less broken than the remainder, and probably in that vicinity was located the original "rock" from which the bed has extended. About the western edge the bed is broken by mud sloughs, and immediately to the eastward of the bed numerous small, detached groups of oysters are found and a few small beds, whose area has been included in that given for the Bird Bed. The oysters, though found over the entire area, are not evenly distributed, but exist in larger numbers on the northern and more solid portion of the bed than elsewhere. The bottom is hard, of shells, with a light covering of mud. On the western portion the substratum was of mud, but elsewhere it was generally hard, probably of sand. To the northward of the bed the bottom was of sand, soft on top and hard underneath; to the south and west soft mud was found. The oysters were single, of medium size, and good quality. No sponge or grass was found, but many old and broken shells. In the vicinity of the muddy bottoms the shells were black and no young were discovered, but on the central part of the main bed, where the shells were of ordinary color and moderately clean, large numbers of young were found. It was noticed that many of the young had been destroyed by the drills, and especially about the solid portion of the bed, where as many as 152 out of 156 on one shell had suffered. As the channel was approached the drills (*astyris*) did not appear to be as numerous nor to have done as much damage, only about one-fourth of the young having been destroyed. The number of oysters to the square yard, the mean of four observations on different parts of the bed, was 0.36.

*Hern Island Bed.*—Originally this bed was south of the channel into Guilford Creek, but by the action of natural causes and by dredging it has been extended across that channel and connected with the Bird Bed. It lies due south of that bed and extends in an east and west direction one mile, and has a width of about one-half mile. Its area is 2,092,000 square yards, and it is next in size to the Bird Bed. The depth of water is from 14 to 22 feet, the shoal water lying a little to the westward of the central portion of the bed, and the deep water being found in the Guilford Channel. The bed is broken about the edges, especially the northwestern one, and where it borders on the Guilford Channel, but elsewhere and in the center it is comparatively solid. A few mud or soft sand spaces were found in the eastern part. The oysters are distributed very evenly over the entire area. The bottom generally is hard, of shells and sand, though only a small amount of the latter was found. In the Guilford Channel and its vicinity the bottom is softer and the substratum of mud. To the southward of the bed hard sand is found, and in the channel to the westward the usual soft mud. The oysters were single, small, and principally of a young growth. Those adult oysters taken by us were of fair quality. Many old broken shells were brought up by the dredge but no sponge or grass. Many young were discovered and a large number, over 25 per cent., had been destroyed by drills. Large numbers of *astyris* were present with the young. The number of oysters to the square yard, the mean of six observations, was 0.29.

*Beds of the Guilford Channel.*—South of the Guilford Flats, on each side of the channel into Guilford Creek, are two narrow ledges of oysters, extending east and west and following the trend of the channel. The northern bed is 1 mile in length, and has its greatest width, of one-third of a mile, at its eastern extremity, and its least, of one-tenth of a mile, at its western. Its area is 585,000 square yards. The southern bed is 1¾ miles long, one-quarter of a mile broad at its western and one-tenth of a mile at its eastern extremity. Its area is 630,000 square yards. The northern bed has an average depth of water over it of 11 feet. The southern has from 9 to 21 feet, the deeper water being on the extreme western part of the bed. Both beds, though narrow, are solid, being but little broken even about the edges. They are old and not frequently worked. The bottom is of mud and shells for several feet, and underneath that a hard stratum. The oysters were scarce, and no young were found.

*Beach Island Bed.*—This is a small Bed, lying about 1 mile NNE. of Beach Island, and south of the narrow channel into Deep Creek. It is irregular in shape and comprises an area of 225,000 square yards. The depth of water over it is from 12 to 17 feet. The bottom is of mud and shells, the stratum being about 3 feet thick on the southern border and increasing in thickness as the channel is approached. Where it could be ascertained the substratum was found to be hard, and is, probably, of sand, as the bottom contiguous is of that description. It is probable that narrow ledges of oysters exist on both sides of the Deep Creek Channel, above Beach Island, but lack of time prevented our verifying the supposition. The bed is unbroken, and the oysters single and presenting the same general characteristics as on the beds already described. A moderate number of young was found, and the presence and destructive effects of the drills were noticed.

*Parker's Bed.*—This is a small bed lying east of Watts' Island, and on the western side of the channel into Pocomoke Sound. It is long and narrow, extends north and south five-eighths of a mile, and has an average width of one-fifth of a mile. The depth of water is from 12 to 24 feet, the shoal water being found about the middle of the bed and the deepest water on the southeastern portion. The bed is unbroken except about the edges, and the oysters are spread uniformly over the area, which comprises 495,000 square yards. The bottom is hard and consists of a stratum, 3 feet thick, of shells and mud, over a stratum of hard sand or clay. The contiguous bottoms are of soft sand or mud, with a hard substratum. The oysters were single, of moderate size, and similar in quality to those on the other beds of the Sound. They were not numerous, the number to the square yard being 0.57, but that number is larger than on any of the other beds in Pocomoke. Some of the red sponge was found, but nothing else. Large numbers of young and drills (*astyris*) were discovered, but for some reason the drills appeared to have been less destructive than elsewhere. Those oysters found near the bed were larger than those on it, but had no young attached to them.

*The Brig Bed.*—This bed lies to the northward and westward and off the mouth of Chesconnessex Creek. It is small, nearly oval in shape, and comprises an area of 517,000 square yards. Its extent east and west is five-eighths of a mile and its greatest width, north and south, is three-tenths of a mile. The depth of water is from 19 feet on the eastern edge to 48 feet on the western. The bed is unbroken, except about the edges, where the oysters are somewhat scattered; on the solid portions they are not very evenly distributed, being more numerous about the center of the bed than elsewhere. The bottom is hard, and probably of sand and shells, but, owing to the depth of water, it was impossible to use the probe successfully; the contiguous bottoms are, however, of the character described, and it is probable that there is no difference on the bed. The oysters were large and single and of superior quality to any on the other beds. A moderate number of young and a few drills were found, but no sponge or grass, though some of the latter was discovered among the scattered oysters. The number to the square yard was 0.27.

### DENSITIES.

The density of the water on the different beds was obtained in the same manner as in Tangier Sound.

The least density found, that of 1.0113, was across the mouth of the Pocomoke River at low water of the spring tide. The water of the greatest density, that of 1.0174, was taken from about the middle of the Sound, over the Bird, Buoy Spit, Muddy Marsh, and Hern Island Rocks. The density over the beds, therefore, would be within those limits, the variation amounting to 0.0061.

The effect of the tide does not appear to be invariable, as the greater densities were found as frequently on the ebb tide as on the flood. The depth of water and the prevailing winds have probably a greater effect than anything else, as the density increases with the depth, and the prevalence of easterly or southeasterly winds, backing the waters of the bay up into the Sound, would have a like effect. As the variation noticeable during the space of eleven days, under various conditions of weather, was so small, it can hardly be much greater at any time, and unless much greater than shown by the records, and if representing the change in salinity, it can have but very little, if any, effect upon the oysters on the beds. By the following tables of comparison it will be seen that the fluctuation of density is, as in Tangier Sound, greatest at the head of the Sound and least at its entrance, with an increased fluctuation where the influence of the Mesongo and Guilford Creeks is felt.

On the beds above the Bird Rock the difference of density noticed was 0.0061. On the remainder of the beds the difference was 0.0015, showing that there is a much smaller change in te density over the southern beds than over the northern.

*Comparison of densites—Pocomoke.*

[The figures show the excess of density over that of distilled water, which is represented by 1,000.]

| Bed. | Maximum density. | Tide. | Remarks. | Difference. | Minimum density. | Tide. | Remarks. |
|---|---|---|---|---|---|---|---|
| On and above Potter's and Slatestone. | 1.0160 | High water and one-quarter ebb. | ........................ | .0047 | 1.0113 | Low water.......... | Section. |
| Shell Bed and above.... | 1.0170 | One-quarter flood .. | 14 feet; calms and light breezes several days. | .0014 | 1.0156 | Three-quarters flood. | 5 feet. |
| Muddy Marsh.......... | 1.0174 | Three-quarters ebb | 18 feet and same as above | .0014 | 1.0160 | One-quarter flood ... | Strong easterly breezes. |
| Buoy Spit.............. | 1.0172 | One-half flood..... | 15 feet and same as above | .0004 | 1.0168 | One-half ebb........ | 15 feet; light breezes. |
| Bird and Hern Island Beds. | 1.0175 | One-half ebb ...... | 4 fathoms and same as above. | .0015 | 1.0160 | Three-quarters ebb . | 18 feet; mouth of Guilford Creek. |
| Mesongo Creek......... | 1.0173 | One-half ebb ...... | 17 feet and same as above | .0007 | 1.0164 | Low water.......... | Eastward station, 7 feet. |
| Guilford Creek......... | 1.0167 | High water ....... | 9 feet; light breezes .. | .0007 | 1.0160 | One-half flood....... | Head of creek. |
| Parker's................ | 1.0172 | One-quarter ebb .. | 12 feet; light breezes .. | .0009 | 1.0163 | One-half flood....... | Light breezes. |
| Brig..................... | 1.0169 | Three-quarters flood. | 11 feet; light breezes .. | .0005 | 1.0164 | Low water.......... | 17 feet; light breezes. |

## CURRENTS.

Over the Pocomoke beds the general set of the ebb current is westerly until it reaches the shoal between and south of Broad and Ape's Hole Creeks, where it turns to the southward into the main channel. The majority of the observations of the ebb current were made during moderate northeasterly breezes, but the direction seems to have been but little influenced by them, though the strength probably was; as at high and low water by the tide tables, when there should have been no perceptible current, one was observed of from 0.1 to 0.2 of a mile an hour. The maximum strength observed was 0.5 of a mile per hour. The flood current sets northeast over the beds, and has a maximum strength of 0.5 of a mile per hour, and is but very slightly influenced in direction by the wind.

In the main channel of the Sound, below the Shell Rocks and over the Muddy Marsh Rocks the flood current sets to the northward, following the general direction of the channel. The maximum strength of this current, when uninfluenced by the wind, was 0.45 of a mile per hour. No observations of the strength of the ebb current were made in the main channel; but it is probably equal, or of slightly greater strength, than the flood, and sets to the southward.

Over the Bird and Hern Island Rocks the flood current sets to the northward and eastward into Mesongo and Guilford Creeks, with a maximum velocity, when uninfluenced by the wind, of 0.24 of a mile per hour. The ebb sets to the southward and westward, curving to the southward as it becomes influenced by the main current, with a maximum velocity of 0.4 of a mile per hour.

North of the Guilford Flats the flood sets northeasterly toward Muddy Creek. The maximum velocity observed during light northerly breezes was 0.3 of a mile per hour. South of the Guilford Flats the current follows the general direction of the channel, the flood having a tendency towards Hunting Creek, where the channel into Guilford Creek joins the latter. The maximum velocity observed during light northerly breezes was 0.5 of a mile per hour.

The ebb out of Mesongo and Guilford Creeks sets to the southward and westward, following the channel until it reaches the Bird and Hern Island Beds, where it curves to the southward. Its maximum velocity was 0.4 of a mile per hour. The current over the Brig and Parker's Beds sets to the northward and to the southward; the maximum strength of the flood, when uninfluenced by the wind, was 0.24 of a mile per hour, but a moderate breeze appears to be sufficient to cause a marked increase of strength and change of direction. Off the mouth of the Chesconessex, where the wind, though light, had the width of Chesapeake Bay and both Tangier and Pocomoke Sounds to sweep over, the flood tide on the third quarter had a set to the northward and eastward of 0.4

of a mile per hour. North of Parker's Bed the flood, on the first quarter, during a moderate southwesterly breeze, was found to set to the northeast at a rate of 0.6 of a mile per hour.

The oystermen greatly overrate the strength of the currents in the Sounds, putting the maximum velocity at about four knots on the ebb and somewhat less on the flood; but I could find no reason that would explain so great an increase over the velocities as established by ourselves, and consequently doubt the value of the estimate.

### DEPOSITS.

The fact that on nearly all the beds, and especially those in the vicinity of the creeks and rivers and in the upper part of the Sound, there is a light covering of mud, more or less thick, over the oysters, would lead to an inference that there must be a deposit of that character going on. On most of the beds the substratum of the bottom was hard and the thickness of the surface-covering gradually decreased as the entrance to the Sound was approached. In the upper part of the Sound shells were found with the mud for several feet, and of such a number and character, being old and discolored, as to forbid the supposition that they had recently sunk in the mud or been covered by it.

The Pocomoke River, draining an extensive tract of the Peninsula, would bring down a large amount of sediment, which the strong ebb current would carry directly over the beds in the upper part of the Sound. The set of the ebb is east, and, as will be seen by the chart, the deeper water lies nearest the southern shore of the upper Sound, and those beds lying to the southward of the channel are the hardest and least broken. The shores are low and marshy, and probably add somewhat to any sediment held by the main current before it enters the Sound.

I infer that there is a deposit going on of maximum amount over the Old Rocks and those to the northward of the channel, and decreasing as the entrance to the Sound is approached. The amount in any given period of time would be difficult to ascertain, but the character will be shown to some extent by an examination of the specimens of bottom. Whether the amount of matter deposited is sufficient in quantity to seriously affect the beds is a matter of conjecture; I should judge that it was not, and my opinion coincides with that of all the oystermen I was able to interrogate. That it must have some effect cannot be doubted, and the evident deterioration of the beds in Pocomoke Sound may be accounted for, to some extent, by the supposition that the effect is injurious; but so many other and more direct causes exist for the deterioration that it is difficult to eliminate their influence. The fact that the beds have existed and have been worked since the first settlement of the country would lead to an inference that the effect, if prejudicial, was very slightly so.

The scattered oysters lying on the sands and those beds in the vicinity of sand-shoals and in shallow water, the Muddy Marsh and Beach Island Rocks particularly, are exposed to damage by "sanding" in a manner similar to certain beds in Tangier Sound, and which has already been described. The large amount of grass, sponge, and sea-weed growing on the sand-shoals, especially the one to the east of Hern Island and south of the Guilford Channel, is frequently torn up by the heavy gales and deposited on the beds with the same injurious effect that it had in Tangier Sound. Heavy southerly gales will sometimes cover the beds above the Buoy Spit and Shell Beds with mud for a short time, but not sufficiently long, it is said, to affect the oysters seriously.

### EFFECT OF ICE AND GALES.

The heavy gales that occur in winter and summer, though principally during the former season, increase or diminish the depth of water on the beds sometimes as much as three feet. Strong northerly and northwesterly gales have the effect of diminishing the depth of water, piling up any floating ice upon the leeward shores, and cutting away parts of those shores. Heavy southeasterly and southerly gales will increase the depth of water on the beds, stir up the soft muddy bottom of the channels and beds above Shell Rock; and, during the winter, in addition to piling the ice on the leeward shores and planted beds near Ape's Hole Creek, will pile it up on the Old Rocks, Buoy Rock, and Shell Rocks. Generally speaking, the beds in this, as in Tangier Sound, are in too much water to permit their being uncovered by even the heaviest gales, or to allow the ice to ground upon them at any time; but those beds in shoal water (of about one fathom), and the planted beds, which are generally in less, are subjected to both evils. The effect of gales and ice in Pocomoke Sound seems to be less than that in Tangier Sound, in consequence of its less extent and smaller area.

### GENERAL INFORMATION GIVEN BY OYSTERMEN.

The following information is that derived from the answers to the questions propounded to the fishermen and others.

All the oystermen and dealers that were encountered during the season, so far as was possible, were interrogated. That which was not pertinent to the subject, or evidently influenced by self-interest or other considerations, has been excluded.

There has been no material change of the channel within the memory of the oldest fishermen, nor have they ever found oysters in the deep water of the main channels of either Sound. With regard to the improvement or deterioration of the beds, it was the general opinion that the beds had been much extended in size, that the quality of the oysters had improved, both as to size and flavor, but that the number on the beds had been very materially diminished, so much so, that it was hardly profitable to work on some of the beds. About thirty years back, the large beds in the Sound were not known to the fishermen and when first discovered and worked, the oysters were in clusters, long and thin valved and of poor quality, though very numerous and easily taken. Since their discovery, and especially during the last ten years, the beds have been greatly overworked and the number of oysters much lessened.

Formerly, the best oysters were found on the Terrapin Sands, and there were none on the sands inshore of the beds; now the finest oysters in the Sounds are found on the sands bordering on the beds and are considered better than any in the general market. All the beds have been much extended by dredging, especially the Bird Rock in Pocomoke Sound and the Great Rock in Tangier Sound, the former being two-thirds larger than when first discovered, and the three rocks, of which Great Rock was originally composed, having been dragged into one continuous bed. Though thus extended, it was the opinion that there were not as many oysters on the beds at present as were found on the smaller areas. In Fishing Bay, at the northern extreme of Tangier Sound, though the beds as a whole had deteriorated, during the last four years there had been some improvement on account of a more rigid observance of "close time."

The cause assigned for the deterioration, and even the admittance of the fact, depended very much upon the occupation of the informant. The tongers, or those who pursued the fishery with tongs alone, were unanimous in laying the deterioration to excessive dredging, while the dredgers, or those owning pungies or other vessels employed exclusively with the dredge, while they admitted the decrease in the number of oysters, laid such decrease to the action of natural and unexplained causes, arguing that the evident extension of the beds and improvement of the oysters, due to dredging, was sufficient to prove its good rather than ill effects.

With regard to the effect of ice in cold weather, every one coincided in the opinion that the oysters in deep water were most affected and those in shoal or brackish water were least so. In the same depths and character of water, those oysters about the edges of "muddy rocks" and close to muddy channels or sloughs were most affected by the cold or a severe freeze. After the latter event the packers distinguish the deep-water oyster by its dark, slimy appearance, and decline it, though at the same time shoal-water oysters are in good order and are accepted. With regard to the quality of the animals, those in the Sounds were considered finer than those in the creeks and rivers, and of the different beds those from the Shark's Fin, Terrapin Sands, and Bird Beds were considered superior. Regarding flavor alone, those from the salt water were the best, and generally the salter the water the better the flavor.

With regard to an increased freshness of water, due to freshets and heavy rains, it was the general opinion that during the winter season it was not of much consequence, but that in spring or summer heavy rains or freshets were very beneficial, especially in the spawning season, hastening its advent and shortening its duration. An increased freshness of water always fattened the oysters. Oysters in salt water were always poor, and oysters were generally poorer after a dry season. Planted oysters above Pig Point and the Old Rocks, in Pocomoke Sound, have been known to die from absorbing too much fresh water, and those on the Old Rocks have sometimes suffered from the same cause; but this only occurs during heavy freshets.

With regard to the depth of water and character of bottom, shallow water was preferred, and sticky mud or mud and sand, about six inches in thickness over a hard substratum, was considered the best, though a larger amount of mud did not matter, provided it was not so soft as to allow the oysters to sink in it and had a strong current over it.

The oysters were said to feed on the flood tide, having their bills open then and at no other time. No one had noticed any enemies or animals that preyed upon the oysters, and all seemed to be ignorant of the drills and their destructive effects.

The oysters are "culled," that is, they are separated from the old shells and other *débris*, while the boat or vessel is on or near the bed. Everything except the oysters is thrown back, sometimes striking the bed and as often the mud. The young oysters under a year and a half in growth and less than two inches long are also thrown back.

All persons interrogated were of the opinion that at least 75 per cent. of the oysters on a bed are taken off each year, and that no more than 50 per cent. should be removed. Off the beds near Haine's Point, at least 100,000 bushels, or about 20,000,000 oysters, were taken in the season of 1878. Off the Great Rock, about 100,000 bushels, were taken by one hundred boats in October and November of 1877. The oysters on the rock at the end of November were so scarce that but a very small number of boats could find profitable work on the bed. In the spring about 75,000 bushels more were taken up and sent north, and as the oysters were small, they amounted to probably 15,000,000 at least. Exclusive, then, of the fishing done during the winter months, in one season it is estimated that 30,000,000 of oysters were removed from one bed alone.

Nearly all the oystermen advocated a "close time," either from April 1 or May 1 to October 1; many considered a prolongation until November 1, and an entire rest every other year, would be beneficial.

With regard to transplanting the oyster and its transportation, all experienced persons were of the opinion that delicacy of handling, and freedom from jars, concussions, and shocks of any kind were desirable. Oysters when under hatches have very frequently been killed by heavy thunder storms and firing of guns. Any concussion or sudden shock will prove destructive if the animals are in a confined space. Oysters taken up during the summer are much more susceptible to injury from this cause than those obtained during the winter.

Oysters are transplanted at any and all seasons, but generally in the spring and autumn. Oysters obtained by the use of the "tongs" are preferred to those dredged, and generally those taken either before or after the spawning season are most desirable. The dredged oysters are apt to be broken about the bills and will die on the planting grounds sooner and in larger numbers than the "tonged" ones. Those oysters planted about the Sounds are generally obtained from "tongers," but those sent to the north, being in such large numbers, are usually dredged. The size and age of the oysters to be transplanted depend on whether they are for early consumption or not. If the former, the larger and older the better, but in the latter case young oysters, from one to two years old, are preferred. Generally any and all oysters are taken, without regard to age or size. The oysters for the northern planting grounds are usually taken up as soon as ice clears away and are used during the spring. Those transplanted in the Sound are taken up later in the spring, or during the early summer or autumn months, and used during the following winter. Blunt-nosed oysters, with thick shells, do not thrive on the planting grounds. A change of bottom in transplanting oysters is not considered of so much importance as a change of water. The planted beds should be laid at the mouths of creeks and rivers having a rapid current. The bottom best for natural beds was considered best for planted ones.

The spawning season was said to be from May until August, inclusive, though most of the spawning was done in June and July. All opinions coincided that the oyster in shoal water spawned first, but differed as to whether, the depth being the same, all oysters on the same bed spawned at or about the same time, as many being for as against the theory. Currents were said to have no effect upon the spawning. Oysters of one year's growth, three-fourths of an inch long, have been seen with the spawn in them, and oysters on natural beds were thought by the majority to spawn sooner than the planted ones, though there was not much difference. Oysters transplanted with the spawn in them, however, will cease spawning. A wet or warm spring would hasten the time of spawning, but would not shorten its duration. Heavy freshets were very destructive to the "spat" in Pocomoke Sound, driving it out into the bay, and large schools of fish, especially trout and tailors, devoured a good many every spring and summer. The young were supposed to "strike" every three years, though there was but little regularity about it, a bed sometimes running for ten years with a young growth on it every year and then failing to produce anything for two or three years. Sometimes one part of the bed will be covered by young, and another part totally barren.

No systematic attempt had ever been made to increase the amount of "cultch" in the Sounds, though a few persons had placed old shells, ballast, boards, and boughs about their planting ground and succeeded in making a good catch. It was the general opinion that the oyster increased in size from one to two inches in the first year of growth and a little more than that during the second; afterwards the increase was much less. Oysters from two to four years old were considered as best for the market, and are then from 3 to 4 inches long.

Ten bushels of oysters were considered a profitable day's work for a tonger. For a dredger the number of bushels varied on account of their different sizes. About 60 bushels were considered a profitable day's work for the larger vessels and from 20 to 30 for smaller craft. The dredging vessels employ from four to nine men, and the "tonging" canoes one man and a boy. Tonging could not be carried on profitably in depths greater than 4 fathoms in the Sound, and dredging in not more than 6. The dredges vary in size, from 2 to 4 feet across the mouth, with from eight to sixteen teeth. Generally they are made about 3 feet wide, with twelve or fourteen teeth, but vary a good deal in weight. My informant found that, generally speaking, it was more profitable to fish with the tongs exclusively, for the large oysters used for barreling by the dealers, and to dredge for packing and canning establishments. The tongs are worked at small expense and the "barrel" oysters bring a much larger price, though they are necessarily selected oysters and more difficult to obtain. The prices paid during the season of 1877–'78 were about $1 per barrel for "barrel" oysters and from 5 to 40 cents for the ordinary oysters from the beds; the "snaps," or most inferior quality, bringing the lowest price, and 40 cents being paid only for "extra culled" oysters. About 20 cents per bushel would allow a small profit. The flavor is not generally taken into account, and the degree of fatness and the size settle the price. Salt-water oysters sometimes command better prices when intended for a special market or to supply some unusual demand.

With the improved appliances in use, as at present, the general opinion was that about twenty or twenty-five years ago one-third more oysters could have been taken in the northern part of Tangier Sound than at present, from two to five times as many about Crisfield, and in Pocomoke Sound nearly seven times as many as at the present day; that without any of the modern contrivances it was possible then for either tongers or dredgers to take many more in a day than at present. The general opinion of all persons in and about the Sounds, with a very few exceptions, was that the beds were being worked much beyond their capacity, and the majority were in favor of extending the "close time" as a remedy for the deterioration. Many thought that a resting time of a year or more would be beneficial. All were in favor of enforcing the law prohibiting the dredging and working of the beds during the "close time," and all testified that there was no attempt toward the enforcement of the law at present, either by the oyster police or any one else.

## CONCLUSIONS.

The foregoing pages, with the record and charts, contain all the data collected during the season for the study of the beds and the conditions affecting the animals upon them. Not regarding it as within my province and not possessing sufficient knowledge of the subject, I have not attempted any study of the biology of the oyster, but have confined my report to as concise a description as possible of the beds and conditions surrounding the various forms of life upon them. The following remarks are simply the conclusions drawn from certain peculiar features and facts established by the investigation and testimony and an attempt to account for them.

In reviewing the remarks upon the different beds, it will be seen that there is a marked absence of oysters classed as "young," or those supposed to be of the last brood, on all beds above Kedge's

Strait in Tangier Sound, and above the Bird Rock in Pocomoke Sound. In Tangier, the young first appeared in considerable quantities on the middle of Muscle Hole Bed and Piney Island Bar. There were none in either the Manokin or Big Annemessex Rivers or on the northern part of Harris' Rock, though large numbers were found on the central and southern portions of the latter. The southern beds of both Sounds were plentifully supplied. Again, on the southern beds there was an absence of the class termed by us "young growth," or oysters apparently spawned during the previous season, while on the northern beds of both Sounds the proportion of this class was very large. Over these different beds the change of density is too slight to enter into the question and the currents too nearly similar, both in direction and strength, to have influenced the difference in production. On nearly all of the northern beds in both Sounds the bottom is muddy or the beds in close proximity to muddy bottoms. To the southward, however, the bottom is hard and the beds surrounded by sand or gravel, except on the edges nearest the channels. Again, all the northern beds in both Sounds are in comparatively shoal water and those in the southern parts in deep water.

There are, then, two similar facts noticed in both Sounds with regard to the presence and absence of the young and "young growth"; the former have been found in deep water and on hard bottoms, the latter in shoal water, on or near soft bottoms. The character of the bottom can hardly be of much importance in this case, for though a hard, clean bottom is necessary for a successful attachment of the "spat," yet the bottoms on the northern part of the Sounds must be sufficiently so to obtain a large quantity, as is shown by the large number of young growth on those beds; and that the absence of the young is not due entirely to that cause is shown by their scarcity on the Chain Shoal and Drumming Shoal Beds in Tangier, and Shell and Muddy Marsh Beds in Pocomoke Sound, where the bottom is hard and moderately clean. Remaining, then, as the only probable cause known to us, is the difference of depth of water.

It will be found upon reviewing the remarks and record that almost invariably the young are found in deep water and the young growth in shoal. It was the opinion of the oystermen that the oysters in the Sounds increased from one to three inches in length in the first year of their existence. The class termed "young growth" by us were from three-fourths of an inch to one and a half inches long; and supposing the oystermen to be correct in their estimation of increase in size, the class termed "young growth" would then be of the same season's brood, spawned much earlier than those termed young. The investigation of the beds was carried on in September, and in Tangier Sound the principal amount of information was collected during the latter part of that month and the first part of October. If, then, the oysters on the shoal-water beds had spawned in the early part of June, they would have had about four months growth when our observations were made. In searching for spawn in the oysters during the latter part of August and first part of September, Mr. Rice was unable to discover any except in those from deep water, and that fact, together with the inference drawn from the preceding paragraphs, leads me to believe the oystermen correct in stating that there is a difference in the time of spawning of the shoal and deep water oysters. There is but one other way of accounting for the absence of young on the northern beds, and that is by accepting the supposition that the "spatting" not only does not occur every year, but that it occurs only on parts of the Sounds during each season. Such is the opinion of many people of experience, but I am inclined, from the results already given, to prefer the other solution of the problem, not having found any reason that would support the opposite theory or lead to its entertainment.* The difference in time of spawning in shoal and deep water is probably due to difference in temperature, the deeper water naturally being of the lowest. The establishment or the refutation of this supposition, as also of that of the difference of the times of spawning, is very necessary, especially of the latter, as it would afford a sure basis for such legislation for the protection of the beds as will soon be necessary.

Aside from the general absence or presence of young on particular beds, it was noticed that a much smaller number were found on or adjacent to the muddy bottoms, or on the sands where there was much grass or sponge. On the beds a large number of young were seldom found where there was much of the red sponge, though there was not always a diminution of the former when the latter was present. The absence of the young may be very readily accounted for if the sponge had formed previous to the "spatting," as it would prevent the exposure of the "cultch." The sponge is of very rapid growth, and I was informed that on an unworked bed it had been known to become three or four feet thick in a few months. If, then, it had formed and commenced growing after the "spatting" season, the young would not be as much disturbed by it as they would if the growth had been previous to their advent. This is another reason in favor of the theory that the depth of the water influences the time of spawning, as the effect of the sponge on the numbers of young was greater in deep than in shallow water.

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* NOTE.—Reference is made to this statement in Report of 1879.

The number of drills (*astyris*) was, generally speaking, in direct proportion to the number of young, and the Pocomoke beds, especially the Bird and Hern Island Beds, appeared to have suffered most from their ravages. A description and sketch of this animal, taken from specimens preserved by me, has been made by Mr. W. H. Dall, Assistant Coast and Geodetic Survey, who has kindly furnished me with copies. Very few star fish and welks and no other enemies were discovered in the Sounds, and the drills are probably the only ones that do any considerable damage.

With regard to the beneficial effect, or the reverse, of fresh water, there can be no doubt that the oysters at least appear fatter and are superior after absorbing it, though they become poorer in flavor. In order to test the effect of fresh water upon them and to determine if the low spring tides had any share in causing the decrease in the numbers on the beds, a dozen oysters were selected from the same bed and haul of the dredge. Six of them were opened immediately and inspected and found to be rather poor, of small size and dark color, but of the ordinary flavor. The remaining six oysters were placed in perfectly fresh water for twenty-four hours, the water being changed several times during that interval. They were then opened and inspected. They were alive and in good order, very fat, or apparently so, and of a creamy white color and much swollen, but of very insipid taste. As the oysters were alive at the end of a day's immersion in fresh water, they cannot well be destroyed by the brackish water of low spring ebbs, to which they would not be exposed for more than six hours, though a continuance of heavy freshets might very seriously affect them. As there is but one river in both Sounds (the Pocomoke) likely to subject the oysters to this evil, for the main beds there is nothing to fear.

The evil effects of sudden jars and concussions are probably due to the breakage of the delicate pedal muscle, which after the spawning season, in common with all other parts of the animal, is in a more or less weakened condition.

In explaining the fact that the oysters in deep water are more affected by cold water and ice than those on the shoals, it is necessary to remember that the lower the temperature of sea water the greater its density, and thus as the surface water becomes cooler it would sink. The freezing point of salt water is below that of fresh. Therefore the oysters in the deep water, or, generally speaking, those remote from the mouths of the streams, may have surrounding them water of a slightly lower temperature, depending upon the amount of salinity, than those oysters near the creeks and rivers that are surrounded by ice. Again, the deep water would be much slower to lose or acquire heat than that on the surface or in less depths, which would necessarily be affected quickly by all changes of weather.

The statement that the oysters recover and reappear after the "sanding" process, must be received with great caution, opposed as it is to most experience. That some few may survive is possibly the case, but that the majority recover after being covered with sand for any length of time is very doubtful.

The testimony of all persons in the neighborhood of the Sounds was to the effect that the beds were deteriorating. In the absence of any reliable observations, extending over any length of time, their opinions must be taken as correct, at least as to the fact, although perhaps only approximately so as to the degree. Accepting, then, the statement, it is necessary to account for the deterioration if possible.

After the original formation and growth of the beds they would at some time, the same conditions continuing, cease their development, neither increasing in size, or in number of oysters, there being a natural limit to expansion in either direction. Supposing, then, a bed to have extended itself as far as the conditions of bottom and water or other natural limit would allow, all future expansion could be only in the number of oysters on the bed; this is limited principally by the amount of food and the room for development (the question of enemies not being considered, as, there being no increase, if they were not in sufficient numbers to prevent the growth of the bed and number of oysters, they would not be sufficient to cause its destruction or deterioration).

The number of oysters would then, on a limited bed, steadily increase as long as there was sufficient room and food supplied them until they had reached their limit, a rather indefinable one, in that direction, the quality of the oysters not being taken into consideration. Having reached that point, the number of oysters to all intents remain the same as long as the conditions under which they had previously lived were not changed. To cause, then, either an increase or diminution of the number of oysters or size of the bed, a new factor must be brought in, when, all conditions being changed, the life of the animals begins anew and progresses differently. As there can be no doubt that both the beds and oysters of Tangier and Pocomoke Sounds have changed greatly in character since their first discovery, in accounting for that change it is necessary to discover the new factor or factors that have been introduced and that have been instrumental in effecting it. Briefly, the change in the beds has been a material expansion of their limits and a material diminution of the number of oysters upon them, and therefore the causes for such changes must be sought among such as it is known would produce like effects.

Disregarding for the present the agency of man in the matter, the question is, What natural cause or causes would both expand the beds and diminish the number of oysters? A bed is extended naturally by the drifting spat or "young brood" attaching themselves to any clean, hard, and moderately rough substance contiguous to the bed. The locomotive powers of the "spat" exist for but a short time, and, except when assisted by the current, they can only move a short distance, and unless some suitable object soon presents itself for their attachment they will sink into the soft bottoms and die.

The principal expansion of the beds so far as could be effected by nature must, however, have been accomplished long ago, the beds being surrounded originally, and indeed at present, by soft bottoms of a character which would be most destructive to the "brood" unless some substance was interposed between it and them for their reception. Natural expansion can only be achieved to any extent in the manner described, and though probably there is and has been a slow extension of the beds due to natural unassisted causes, their great increase in area during the last thirty years must be assigned to other agents.

The diminution of the number of oysters may be effected by several natural causes. An increased deposit of earthy or vegetable matter upon the beds would, if in sufficient quantities to bury the oyster, effect the destruction of both old and young; but no such deposit has been noticed, nor could it well occur without showing its presence in other ways, principally by changing the channels and causing shoals, and no such changes have occurred, my investigation showing but slight deviations in either channels, shoals, or character of the bottom from that established by the first hydrographic survey of the locality. A change in the character of the water and bottom which would probably follow a change of channel, and might occur without such change, might, by depriving the animals of their proper food, cause their deterioration and destruction; but such a change, though it would certainly diminish the number on the beds, would do so suddenly and the evil effects would be noticed in the oysters remaining, their quality and flavor, indeed their vitality, being very much impaired. No such impairment has been observed, however, the oysters being larger and finer than when the beds were first discovered. That fact alone will eliminate many quantities from the equation, for any natural cause injurious to all the oysters on the beds would be evident at once by an examination of those found at present. If, however, the destruction or non-production of the necessary number of young is accomplished by means that are not harmful to the mature oyster, a cause is discovered for the diminution of all, in harmony with the existing facts.

Considering first the destruction of young; large numbers, immense when compared with the production of other animals, are without doubt naturally destroyed by the falling of the "spat" upon unfavorable grounds, the prevalence of heavy freshets which would drive the "brood" into the bay and probably cause its loss, and the ravages of various enemies. But all these causes have been in operation continually since the first formation of the beds, and the animals have survived and increased while contending with them. Therefore an increase of power for injury must be assigned to one or all of these to account for the diminished number of oysters. Probably the "spat" falls on more favorable ground since the beds were discovered than was formerly the case, owing to the increased amount of "cultch" due to the fishing of the beds, and aside from that the conditions surrounding and operating upon the beds are so similar to those in the past that the loss of the young could not be much greater from the want of attachment.

The freshets and other natural causes for diminished numbers of young have also been long in operation and the deterioration cannot be justly assigned to them. Remaining then to be accounted for are the ravages of enemies. Those found by us during the season were *astyris* in large numbers, a few welks, and a very few star-fish, but as the oystermen were ignorant of both their presence and destructive effects I am unable to decide whether they have increased or diminished in numbers. There is no doubt that very large numbers of young are destroyed by the drills or welks; fully fifty per cent. on some beds in Pocomoke Sound, and if these small enemies have only within late years entered the Sounds we have one of the principal causes for the deterioration of the beds. But as there is also a marked deterioration upon those beds upon which no drills were found, still another cause must be at work and must be sought in the non-production of the young.

This is caused by the failure of the "brood" oysters, they having been removed or become extinct, thus causing a failure of impregnation. If the theory is correct that there is a mutual fecundation, partaken of by all oysters on the beds, the spermatozoa being formed and milted somewhat prior to the formation of ova, then it can easily be understood that if the oysters are so much separated that even the tides and currents cannot bring the spermatozoa within reach of the adjacent animals, there could be no production of young. Taking for instance the most exaggerated case in both Sounds, that of the Muddy Marsh Bed, it will be seen that the set of the current over it is not generally from any other adjacent bed, the nearest one being Parker's Rock, which is over 3 miles distant; the oysters on the Muddy Marsh Bed were very few, and the mass of shells immense, affording ample surface for the attachment of the drifting "spat," should there be any. But supposing the oysters on the beds to have been so much diminished that they were not sufficient for mutual fecundation, the distance and situation of other beds is such as to prevent the current from bringing the products of generation voided on them to the Muddy Marsh rocks, and there would be, as was noticed, an almost entire failure of young. In the same, though less degree, would the other beds suffer, the amount of spawn voided depending not only upon the number of mature "brood" oysters, but upon their distance from each other and the spaces separating the beds. This theory is supported by the investigations that have been made in England, France, and Prussia, and almost all opinions coincide that the number of young in any spatting season is dependent upon the number of "brood" oysters upon the beds. Indeed, it seems so self-evident a proposition that it is hardly worth while to experimentally establish it. It is necessary, then, having accepted the theory, to determine what proportion of the oysters should be taken off the beds, and what proportion is actually removed. As there is no data to my knowledge derived from observations made in this country to determine the first of these two desired points, it is necessary to turn to the experience of foreign oyster fisheries for guidance, and though the animals and the conditions under which they live are not entirely similar, yet some information may be obtained and a line of investigation marked out for the future.

The following is a synopsis of the deductions of Professor Karl Möbius, professor of zoology in the University of Kiel, whose work, in manuscript, on the oyster was kindly lent me by Professor Baird. The observations were made over the Schleswig-Holstein oyster beds by government officials from 1730 to 1852, and were carried on in, practically, the following manner: Each bed was dredged over in three or six places, according to its size, and the oysters taken were divided into three classes and carefully counted. The classes were denominated "marketable," "medium," and "young growth." The "marketable" oysters were full grown and mature, from 7 to 9 centimeters in length and breadth, and 18 millimeters thick. The "medium" were half-grown oysters, from 16 to 18 millimeters thick and of less than 9 centimeters in breadth. The "young growth" were those one or two years old. From these observations Professor Möbius discovers that there was an average of 421 medium oysters to 1,000 full-grown ones. The average of all the observations differs very little from the number given by each, and consequently shows that there was but slight fluctuation in the proportion in one hundred and twenty-two years. The medium oysters are considered by Professor Möbius to be those descendants of the marketable ones that have survived their most precarious years of existence and escaped their principal enemies, and are consequently likely to reach their full growth. They thus represent the total number of embryos spawned which have survived in the struggle for existence.

From his (Möbius') experiments he decides that an oyster spawns about 1,000,000 embryos in a season, and that 44 per cent. of the mature oysters give forth "spat." [Other authorities are of the opinion that only about 10 per cent. spawn; Professor Möbius' data appear hardly sufficient to justify his conclusion.]

From the above it is evident that in an assemblage of a thousand oysters, 440,000,000 embryos will be voided every season, and of them 421 would survive, or 1,045,000 embryos would be destroyed where one was preserved. But the medium sized oysters also spawn, though they send forth a much smaller number of embryos. Möbius estimates that the 421 in the community would produce about 60,000,000 of "spat." It would therefore require about 500,000,000 embryos to produce 421 medium oysters, or 1,185,000 to produce one. Regarding these results, Professor Möbius is of the opinion that no more than 40 per cent. should be removed each year, but, in my opinion, in order to maintain the oysters at a constant number in the above case, no more than 25 per cent. should be taken, as the one oyster in four would be replaced each year. No comparison between the Schleswig Holstein beds and those on our coast can well be instituted, but as the beds in Tangier and Pocomoke Sounds are of greater extent, and as the more extensive the bed the greater the breeding power, I should consider that, until the annual number of mature oysters produced is known, it would be safe to take about 50 per cent. from the beds, supposing them to be in good condition. That is but an estimate, and may be an erroneous one, but certainly it is not too small. It now remains to be seen what number of oysters are actually removed from the beds. I regret that statistics of the oyster trade in the Sounds are not at hand for reference, and also that the pressure of other work while I was in that locality prevented me from obtaining them. Such observations as we were able to make, however, will furnish a basis for a somewhat rude estimate of the number of oysters and young taken off the beds during the season.

While in Crisfield Harbor, about the 11th October, we counted fifty-seven sail oyster dredgers. The number of bushels carried by them was estimated, and the estimate subsequently verified by the statements of the masters of the several vessels in each class. The following table shows the result for one day:

TABLE I.

| Class. | Number. | Number of bushels. | Average number of bushels to each sail. | Class of vessel. | Number. | Number of bushels. | Average number of bushels to each sail. |
|---|---|---|---|---|---|---|---|
| Schooners | 37 | 2,075 | 56 | Buckeyes | 4 | 45 | 11 |
| Sloops | 12 | 256 | 21 | Canoes | 4 | 32 | 8 |
| Total | | 2,331 | | Total | | 77 | |
| | | 77 | | | | | |
| Grand total | | 2,408 | | | | | |

The day had been a bad one for dredging, and but a small number of dredgers had been at work, and they had come into port much earlier than usual; consequently the average and total number of oysters are below the usual figures. On the same day, in order to ascertain the number of young attached to the mature oysters that were taken off the beds, I had three samples, of a peck each, selected from different vessels entering the harbor and the number of young on the shells counted. The vessels were of different sizes and from different localities. The results are shown in the table following:

TABLE II.

| Vessel. | Number bushels. | Number of young to the peck. | | | Bushel average. | Localities from which obtained. |
|---|---|---|---|---|---|---|
| | | First. | Second. | Third. | | |
| Sloop | 13 | 13 | .......... | .......... | 72 | |
| Schooner | 30 | 93 | 125 | 163 | 508 | The small proportion from Great Rock, the large from Terrapin Sands. |
| Buckeye | 15 | 33 | .......... | .......... | 132 | Deep Water Rock, Kedge's Straits. |
| Sloop | 23 | 73 | 88 | .......... | 322 | Paul's Rock. |
| Schooner | 90 | 76 | 78 | .......... | 308 | Great Rock. |
| Schooner | 65 | 32 | 67 | .......... | 192 | |
| Schooner | 80 | 55 | 89 | 57, 40 | 221 | Great Rock and Thoroughfare. |
| Buckeye | 10 | 1 | .......... | .......... | 4 | Paul's Rock (Sands). |
| Buckeye | 25 | 49 | .......... | .......... | 196 | Great Rock (northern part). |
| Schooner | 50 | 64 | 39 | 23 | 168 | Great Rock. |
| Schooner | 150 | 67 | 35 | .......... | 205 | California Rock. |
| Total | | | | | 2, 228 | Average 202 per bushel. |

The total number of bushels brought into Crisfield, as seen by Table I, amounted in one day to 2,408, and estimating the number of oysters to a bushel to be between 150 or 200, we have for the results of one day's fishing from 361,200 to 481,600 oysters and about 486,000 young. During the progress of the work in the Sounds, there were twenty-four counts made of the dredgers in sight from the vessel. In order that some idea may be formed of the number of oysters taken by these dredgers, an estimate has been made, based upon Table II, of the number of bushels and young carried off the beds. In forming the estimate, all the vessels in the Sound were divided into three classes—the first being an assemblage of all the different craft, the second only the smaller classes, and the third, where about two-thirds were small, and the remainder large craft. The number of sail counted was then placed in one of these classes, we having observed when among the dredgers the particular class and size of vessel usually working over a particular ground. In order to ascertain the number of bushels to each vessel, the total number of bushels brought in (2,408) was divided by the number of sails (57), which would give 42 bushels as the average to a sail. A closer estimate is obtained from Table II, where the number of bushels assigned to each craft is that given by their master. The total number of bushels (551), divided by the number of sail (12), gives 45 and a fraction as the number of bushels to each sail. I have divided by 12 instead of 11, because the last number in Table II was the result of two days' dredging.

The average number of bushels per sail for the second class, by Table I, is 16.6 bushels; by Table II, 17 bushels. The average for the third class is, by Table I, 29 bushels; by Table II, 33 bushels. In all cases the smaller numbers have been used in calculating the number of bushels of oysters. The total number of bushels taken from the beds in both Sounds in thirteen days was 47,842, and allowing from 150 to 200 oysters to a bushel (though the number is probably larger), there would be removed from the Sounds in the very first of the season from 7,176,300 to 9,568,400 oysters. This, however, is far below the real number, as the entire area and number of sail were not visible at the same time.

In order to estimate the number of oysters removed from the beds in each day, I have divided the Sounds into four sections. The first section comprises all of Tangier Sound north of Little Island and the Mussel Hole Bed. The second section comprises all of that part of the Sound, including the Manokin and Big Annemessex Rivers, between Little Island and Jane's Island. The third section comprises all of Tangier Sound south of Jane's Island. The fourth section all of Pocomoke Sound.

Assembling the number of dredgers known to have been dredging on these different sections and the number of bushels taken by them, I have deduced the following results:

| Locality. | First section Upper Tangier. | Second section Middle Tangier. | Third section Lower Tangier. | Fourth section Pocomoke. |
|---|---|---|---|---|
| Total number bushels taken * | 15, 135 | 10, 115 | 18, 060 | 2, 673 |
| Numer of days | 4 | 4 | 6 | 3 |
| Average per day | 3, 783 | 2, 523 | 3, 060 | 891 |
| Average number oysters per day | 567, 450 | 378, 450 | 459, 000 | 133, 650 |
| Grand total taken off in one day | | | | 1, 538, 550 |

* 150 oysters are given to the bushel.

Though there were dredgers in large numbers at work early in September and also many during the entire summer, yet in order that any error may be under, rather than over estimation, I will consider the working season to be from the 1st of October to the 1st of May and allow three days in each week for bad weather which would prevent dredging. That allowance will leave 120 working days, and in that time, by the preceding table, over 184,600,000 oysters would be removed from the beds in the Sounds, supposing them to supply the same number during the entire season.

By Table II it will be seen that the average number of young to a bushel was 202. That number represents the number of young oysters attached to the shells of the full-grown ones that were removed from the beds. That the estimate is not above what is actually the case I am certain from the immense numbers of young brought up by our own dredging operations. In making up the estimate 20 and 30 young were frequently found on one shell, and in one case 54 were counted. In estimating the total number removed from the beds in one day, only those vessels dredging on such beds as were known to have a large proportion of young upon them have been considered, and even then the estimate reaches the astonishing figure of 1,238,790. These oysters are those of from two to five months' growth, and may be said to have survived the most precarious portion of their existence, their shells having become hard enough to resist the drills to a certain extent, and they being firmly attached to the mature oyster, and in no danger of destruction from any cause to which it would not be equally exposed. Still, many of them would doubtless perish even if undisturbed, for though all oysters on the beds, mature or others, would suffer if exposed to unfavorable conditions, yet many of those conditions would affect the young and young growth to a greater degree than the mature and more hardy oysters. I will therefore suppose that 50 per cent. of the young taken up would never have reached maturity, and will also make another and very liberal supposition, that by the 1st of April the young would have reached such a size as would make it profitable to open them. That would make the working season, so far as the young were concerned, 104 days, and the number of young removed would amount in that time to 128,834,000, of which about 64,417,000 would probably have attained their full growth. These young are a total sacrifice, never seeing the water again after their removal and generally perishing on distant or adjacent shell heaps.

Many more are probably destroyed by carelessness in disposing of the old shells brought up by the dredge. The dredging is usually across the bed, and the shoal hard ridges noticed along the edges of the beds on the western side of Tangier Sound and on all edges adjacent to muddy bottoms are no doubt caused by the dredgers, who, as they approach the edge of the bed, having dragged across it, haul in their dredges just before getting over the muddy bottoms. They then stand on, tack or "wear," and as soon as on the bed drop the dredges again. In the mean time the crews have been busily "culling" the oysters, and, as likely as not, have thrown over on the soft mud a far larger number of young attached to the shells than they have taken off on the oysters. No account has been taken of the number of mature or young oysters removed by the tongers, and the estimates are based upon observations made at the commencement of the fishing season, when, the prices being low, a smaller number of dredgers would be at work; therefore, there is every reason to believe that the estimate of both classes of oysters is under rather than above the real number removed. We have, then, aside from the ravages of the drills, a yearly destruction of over 64,000,000 young and the removal of 184,600,000 mature oysters to account for the deterioration of the beds.

Whether this extensive fishing is beyond the capacity of the beds or not, cannot be accurately stated; the only information on the subject obtainable being the statements of the oystermen that the beds are deteriorating from that cause. But an estimation of the effect of excessive fishing may be formed by examining its results upon such beds in England and France as have records upon the subject. The most instructive of these are the records of the production of the beds of Cançale Bay, on the northwest coast of France, which extend over a period of sixty-eight years—from 1800 to 1868. The beds in the bay comprise an area of about 150 acres, and from 1800 to 1816 produced from 400,000 to 2,400,000 a year. This, however, was the period of the Napoleonic wars and the fishing was much disturbed by the presence of the English cruisers. During this time the beds became so thickly stocked that the oysters were in some places a yard thick. After the close of the war the fishing improved and the oysters were removed in larger and increasing numbers until 1843. From 1823 to 1848 it is supposed that the dredgers were living upon the oysters accumulated during the period of enforced rest, from 1800 to 1816. In 1817 the number of oysters produced was 5,600,000, and until 1843 there was a constant increase, the number taken in the latter year being 70,000,000. In 1848 it was 60,000,000; thenceforward there was a constant decrease. From 1850 to 1856 the decrease was from 50,000,000 to 18,000,000, supposed to be the effect of overdredging. From 1859 to 1868 the decrease was from 16,000,000 to 1,079,000; the oysters having almost entirely disappeared from the beds, though on account of the suffering condition of the inhabitants of the shores it was almost impossible to prevent it. In 1870 there was a complete wreck of the bottom which could only be remedied by a total prohibition of the fisheries for several years.

From the beds of the districts of Rochefort, Marennes, and island of Oléron, on the west coast of France, there were taken in 1853–'54 10,000,000 oysters, and in 1854–'55 15,000,000. On account of exhaustive fishing, in 1863–'64 only 400,000 could be obtained.

According to the testimony of Mr. Webber, mayor of Falmouth, England, about 700 men, working 300 boats, were employed in a profitable oyster fishery in the neighborhood of Falmouth until 1866, when the old laws enforcing a "close time" were repealed, under an impression that, owing to the great productive powers of the oyster, it would be impossible to remove a sufficient number to prevent the re-stocking of the beds. Since 1866 the beds have become so impoverished from excessive and continual fishing that in 1876 only 40 men and 40 boats could find employment, and small as the number is, they could not take more than 60 or 100 oysters a day, while formerly, in the same time, a boat could take from 10,000 to 12,000.

According to the statement of Mr. Messum, an oyster dealer and secretary of an oyster company at Emsworth, England, made before the Commission for the Investigation of Oyster Fisheries, in May, 1876, there were in the harbor of Emsworth, between the years of 1840 and 1850, so many oysters that one man in five hours could take from 24,000 to 32,000. In consequence of overfishing, in 1858 scarcely ten vessels could find loads, and in 1868 a dredger in five hours could not find more than *twenty oysters*.

The oyster fisheries of Jersey, in the English Channel, afforded employment to 400 vessels. In six or seven years the dredging became so extensive and the beds so exhausted that only three or four vessels could find employment, and the crews of even that small number had to do additional work on shore in order to support themselves.

The foregoing are a few of, though by no means all, the instances that may be quoted in order to show the disastrous effects of overworking the beds, and in concluding the remarks under that head it will be instructive to extract from Professor Möbius' work his prophecy with regard to our own beds, which is here introduced:

"In North America the oysters are so fine and so cheap that they are eaten daily by all classes. Hence they are now, and have been for a long time, a real means of subsistence for the people. This enviable fact is no argument against the injuriousness of a continuous and severe fishing of the beds. * * * But as the number of consumers increases in America the price will also surely advance and then there will arise a desire to fish the banks more severely than hitherto, and if they do not accept in time the unfortunate experience of the oyster culturists of Europe, they will surely find their oyster beds impoverished for having defied the *bioconotic* laws."

The question now to be decided is how the protection of the beds and their improvement is to be brought about. The protection laws of the State of Maryland, which govern the larger part of the Sounds, are, briefly, as follows: Dredging is allowed from October 1 to May 1. Taking of oysters in other ways from September 1 to May 1. Dredging is not allowed in the rivers and creeks of the Sounds or in their mouths. No steam dredges are allowed. All dredgers and "tongers" must be licensed. Violations of the law are punished by not more than two years imprisonment nor $200 fine. For the enforcement of these regulations there is established a State Fishery Force, consisting of one steamer and several small sloops; one of the latter having jurisdiction over Tangier and Pocomoke Sounds. The officers of this Fishery Force and the sheriffs and constables of the different counties are empowered to make arrests and enforce the law.

The above is the amount of protection afforded by the law if carried out. In the Sounds, in reality, there is none. Neither the State Fishery Force, sheriffs, constables, or any other persons make arrests or enforce the law, the public opinion of the community being against such a proceeding, though every one recognized the necessity when considered in the abstract. I have seen numbers of dredgers at work and the police boat cruising among them, and this was during the latter part of August, when, if at any time, the oysters should have been free from disturbance.

Before deciding upon the measure of protection to be given to the beds, it may be well again to see what has been accorded by foreign governments and with what success. On the Schleswig-Holstein banks the "close time" is from the 9th of May to the 1st of October; no oysters less than 2½ inches in length are removed at any time. The law is enforced, and still the beds are deteriorating.

In Ireland, the "close time" is from May 1 to September 1, and in some localities of the coast from the 1st of April and the 1st of March until the 1st of October and the 1st of November. It is unlawful to dredge or have in possession any oysters or oyster brood during the "close time." The inspector of fisheries can call a meeting of interested persons to decide upon a change of "close time." Inspectors are empowered to permit the planting of oysters and to prohibit the presence of dredges on board any boat during the "close time." The coast guard and constabulary are empowered to enforce the laws, and violators are suitably punished.

The deep-sea fisheries for oysters in the English Channel are governed by rules adopted by England and France. The "close time" is from the 16th of June to the 31st of August. Any boat having a dredge, or other implement used for taking oysters, during that time, is considered as having violated the law. Competent courts of each country have power to punish offenders and the cruisers of each nation power to enforce the law, which is strictly observed by the French fishermen and frequently violated by the English.

In France the oyster beds are protected by stringent and effective laws, which may be briefly stated as follows: The government assumes control over all oyster banks and fore-shores. As occasion may seem to require, an entire bank, or part of it, may be reserved from dredging for a certain time, decided by the local commission. The general practice seems to be to buoy off a third or fourth of a bank each year, which portion is only sufficiently dredged to remove weeds, mud, vermin, &c.; the remainder of the bed is opened to all licensed persons for a certain specified time; the following year another part of the bank is reserved, and occasionally parts are reserved for a longer period. The local commission decides all matters pertaining to the beds and their vicinity, and is composed of the following officers: The inspector of the fisheries, the commander of the fishery guard, two "*Gardes-Maritimes*," one fisherman, master of a boat. The following are the most important regulations made for the guidance of the commissions by the minister of the marine: The beds should not be opened for fishing until the spat has acquired strength to resist the action of the dredge; until the end of January, for example. When a bed has well established breeding capacities, a fourth or fifth part of its total area should be set apart as a reserve, and dredging over such part entirely prohibited. A fishery-guard boat should, whenever practicable, take part in the working of each bed. When a bed is foul or encumbered with weeds or other matter noxious to the development or adherence of spat, it should be open for dredging until cleaned. Beds on which there is never any production of spat shall be opened all through the season. After the working of any bed is over, it should be carefully inspected and, if necessary, the cultch replenished. The "close time" is between the 1st of May and the 31st of August, and is strictly observed. The foregoing regulations have caused a great improvement in the beds on the French coast, and the regulations of other nations have been made and enforced in time to prevent the depletion of their beds.

As an instance of the effect of this protective policy, when understandingly conceived and rigidly enforced, the beds in the Bay of Arcachon are a good example. In 1870, through over-fishing, they had become entirely exhausted; but, by the strict protection afforded them, their fecundity has once more become so great (in 1876) that the waters of the bay from June until August are filled with the young swarm. On a bed when dry, at low spring ebbs, comprising 26.7 acres, there were taken by forty or fifty persons, in about two and a half hours, 60,000 oysters. That part of the bed was immediately buoyed, and no more fishing allowed during the season.

Having seen what is considered necessary for the protection of the beds by European nations, and why it is necessary, the question is, how we can best use their experience. The best remedy for any evil is the removal of the cause, and we have concluded that the cause of the evil in Tangier and Pocomoke Sounds is over-dredging and the destruction of the young brood. Therefore, until the rate of production and the proportion between the number spawned and the number reaching maturity is decided, only a specified number should be taken off of each bed in the Sounds. If observations, both as to the number removed and the increase or decrease of the number to the square yard were continued, a basis might be found for the establishment of the maximum number to be removed; but until that number is established no working of the beds should be permitted between the middle of April and the 1st of November, and none of the beds in Pocomoke Sound should be dredged over at all, except so much as it is necessary to clean them.

There should be a sufficient number of oyster guard-boats to superintend the dredging, both in general and when for cleansing purposes, to collect statistics as to the number of young and mature oysters removed, and to make all observations as to the number to the square yard. They might also collect a good deal of other useful information while on the beds. During September and October they should examine the beds, in order to ascertain the number of young, and those beds having a large proportion should be reserved from dredging operations until the young are able to resist the action of the dredge. No oysters below a certain size should be taken off the beds, and it should be punishable to have those under the specified size in possession. Whenever it is judged that any bed open to general fishing is being worked beyond its capacity, the oyster guard should have power to prevent any further dredging on it. When any bed with a large number of young upon it is open, either the packers or fishermen should be compelled, as far as possible, to return the shells to the beds, or the hard bottoms surrounding them, within a certain specified time, provided that the oysters were opened in their immediate vicinity. Large numbers of young would thus be saved, and the areas of the beds increased. No one should be allowed to take or to possess an oyster having more than a specified number of young attached to it. During the time when not otherwise employed, the oyster guard-boats could be usefully engaged in removing the weeds and grass from the sand shoals and the moss from the closed beds. It must be remembered that dredging is not an unmixed evil, and that the improvement of the oysters and the extended areas of the beds are mainly due to it; but it should be conducted under suitable restrictions, and in this connection may be advised the use of the scrape where it is now prohibited, and the prohibition of the heavy dredges in shoal water and on the soft bottoms.

If there is any animal known to naturalists that is an enemy of the drill and not harmful to the oyster, its introduction into the Sounds would be a great benefit; and, finally, if in the spring either the State or the fishermen would collect the shells from the piles about the packing-houses and deposit them on the hard bottoms contiguous to the beds, they would furnish an excellent "cultch" for the "spat," and probably make a good catch and a permanent extension of the oyster ground.

I have made the above suggestions with the hope that they may in some way bear fruit for the benefit of those engaged in the oyster fishery in the Sounds and Bay. Some more adequate protection than that now offered must soon be afforded, or loss and distress among the large number of people in Maryland and Virginia engaged in the fishery will soon follow from the failure (and that more or less sudden) of the oyster industry. In concluding this part of my report, I cannot do better than to again quote Professor Möbius, whose remarks on the preservation of natural banks of oysters are well worthy of attention:

"In conclusion, I hereby give as the foundation for all oyster culture the most important rules for the improvement of the natural oyster banks.

"First. An oyster bank will yield permanently the greatest profit if it possesses such a stock of full-grown oysters as will be sufficient to maintain the fecundity of the bank in accordance with its bioconotic conditions.

"Second. When the natural conditions will admit of it, the yielding capacity of an oyster bed may be increased by improving and enlarging the ground for the reception of the young brood. The natural banks should be improved by removing the weeds and plants with dredges and properly constructed harrows, and by scattering the shells of oysters and other mussels over the bottom. When circumstances will permit, all the animals which are taken in the dredge, and which kill the oysters or use up their food, should be destroyed. It would be much more judicious and much better for those who eat oysters if the 'close time' could be extended until the 15th of September or the 1st of October, so as to allow the oysters some time after the expulsion of the contents of the generative organs to become fat before being brought to the table. If it is desired that the oyster banks should remain of general advantage to the public and a permanent source of profit to the inhabitants of the coast, the number of oysters taken from the beds yearly must not depend upon the demands of the consumers or be governed by high price, but must be regulated solely and entirely by the amount of increase upon the beds. The preservation of the oyster beds is as much a question of statesmanship as the preservation of forests."

## INVESTIGATION CONDUCTED DURING THE SUMMER AND AUTUMN OF 1879.

My assistants during this season were Master H. H. Barroll, U. S. N.; Ensign W. H. Allen, U. S. N.; Mr. W. E. W. Hall.

Mr. Barroll had charge of the compilation and arrangement of the statistics collected, and, in the field, general charge of the work during the absence of the chief of the party.

Mr. Allen calculated the number of oysters to the square yard, and the ratios between the classes; he also tested the water specimens and developed the curves illustrating the changes and range of density.

Mr. Hall was charged with the care and arrangement of the records so as to facilitate their study by myself and others.

### INSTRUCTIONS.

The instructions of the Superintendent, issued June 30, 1879, desired that the vessel and party should proceed, as soon as possible, to the lower Chesapeake Bay, and continue the investigation begun and prosecuted during the previous season. The instructions were concise, and, being supplemented by verbal ones, were expressed in general terms. It was intended that the scope of the investigation should include as much of that called for in the instructions for the previous season and such additional matter as the judgment and experience of the chief of the party should dictate. The vessel sailed from Baltimore, Md., for Tangier Sound on July 3, 1879, and the field work was completed on the 30th of October, when she arrived at Philadelphia, Pa.

### PLAN OF WORK.

In devising the original plan for the work of the season it was expected that, not only would the party be much larger than it actually was, but that it would be in the field much earlier in the season. This original plan was, briefly, as follows: One division of the party, in a small steamer, was to continue the delineation of the beds and the search for such new ones as might exist. The extension of the survey was to be from Tangier Sound along the eastern shores of the bay.

The other division of the party was, in the Palinurus, to continue the study of the beds already surveyed, the conditions affecting the oysters, and determine, if possible, the effect of changes of temperature and density upon the production and subsequent life of the spat and mature oyster. They were also to ascertain what was the increase in size of the oyster in a given time, and determine the number of oysters surviving in each successive period of life, or establish the natural ratios between the different classes. It was also intended that this branch of the party should obtain, if possible, satisfactory information in regard to the sex of the oyster, the method of propagation, the number of embryos spawned, and the habits of the animal during the early stages of life; or, in general terms, it was intended to make the study of the embryology of the oyster part of the work of the party.

It was proposed to continue this branch of the inquiry throughout the year, and to make, by means of self-registering thermometers and careful series of density observations and chemical analyses, an exhaustive study of the character and changes of character of the water surrounding the animals on the beds.

Another division of the party was to undertake the collection of statistics, and was to visit and inspect all the dredging vessels and packing houses, that some value might be assigned the dredging factor, to which most of the evils affecting the beds appeared to be due.

The smallness of the annual appropriation made it impossible to carry out the original plan, which was accordingly modified; and the want of funds, which reduced the size of the party and scope of the work, also prevented our getting into the field before July 1. Thus the opportunity for studying the embryology of the oyster and many other matters of interest relating to the reproductive processes was unavoidably lost. It was decided, however, to attempt the execution of the original design so far as was possible with the diminished force and time at our disposal, but upon our arrival at Crisfield, Md., it was found necessary to again modify and change our plan, or else duplicate an investigation that had already been undertaken and ably executed.

Members of the Johns Hopkins Zoological Laboratory had been established at Crisfield for some months prior to my arrival, and Dr. W. K. Brooks had begun the study of the embryology of the oyster, had made experiments in impregnating the ova with the spermatozoa, and had succeeded to some extent in raising the oyster from the egg. The study of the embryolgy of the oyster was thus not only undertaken but concluded, so far as was possible, during that season. The results were alike surprising, interesting, and valuable, and, having been accomplished by so able a worker, did not need any confirmation at our hands, and as it was his intention to continue his experiments in the future and trace the development of the oyster up to the point of attachment, I wrote to the Superintendent proposing a new scheme for the season, which met with his approval, and which contemplated the abandonment of all investigation of the embryological life of the oyster.

The work of the party during this season was, properly, the collection of such information as would conduce to correct answers to the following questions:

1st. Were the oyster beds improving or deteriorating?

2d. What were the causes for such improvement or deterioration?

3d. How is the deterioration, if existing, to be prevented and the beds improved?

In the endeavor to answer these questions it was necessary to investigate many problems and to collect much information having apparently but little bearing upon the main question, but it was my endeavor to limit the extent of the inquiry as much as possible and to direct all the energies of the party to the decision of the three points mentioned.

Though the biology of the oyster should be studied, yet only so much of it was essential to the work he had undertaken as would assist in the solution of the problem presented, and consequently it was desirable to leave an extended investigation in that line to others and to settle ourselves only such points as would, as far as we could see, directly assist us in arriving at correct conclusions.

The investigation conducted during the summer and autumn of 1878 had shown that the beds were deteriorating rapidly, and so far as could be seen the principal cause for this deterioration was the over-fishing of the beds. The remaining question to be answered was, then, how the deterioration was to be prevented.

The main cause was decided to be excessive fishery, which, by removing too large a number of mature brood oysters, diminished in a constantly increasing ratio the fecundity of the bed. Other causes operated also to some extent, but their effects were inconsiderable.

There is but one method of maintaining the fecundity of the beds, and that is by protection, but this protection can be afforded in several ways: Either by restricting the fishery, by enlarging the field for the dredgers, or by insuring the maturity of a larger number of oysters, by artificially impregnating the ova of the female and protecting the resultant embryos during those periods when they are unable to protect themselves.

To afford protection and maintain the fecundity of the bed in the last-mentioned manner has been attemped by Dr. W. K. Brooks, and his efforts have been in a measure successful. The ova has been impregnated, and the life of the resultant embryos has been maintained for varying periods, the maximum being six days. Whether this success will be of practical benefit remains a matter of conjecture, but should it prove practicable to thus assist nature in maintaining the beds at their greatest productiveness, it will require extended experiments before we can feel assured that the protection afforded in this manner will be sufficient. To confirm the opinion as to the deterioration of the beds, and to show the best method of protecting them in the two remaining ways, has been the endeavor of the party under my command, and to that result have our efforts been directed.

In the absence of positive and correct information as to the life and habits of the oyster, all legislation relating to their protection must be to a great extent inoperative and non-productive of the desired results, and until such information has been obtained the best and easiest remedy for the deterioration would be an extension of the known fishing ground; in other words, the discovery of new and well-stocked beds; as, the number of dredgers being, at least for a few years, constant, they will naturally seek the most profitable field for labor, and leave the overworked beds for the newly-discovered ones, thus giving the former a chance for recuperation. That this is the case is evident by the record of statistics, most of the dredging vessels working on the new beds outside the Sound and on those in the Potomac River on account of the poor returns given by the beds in Tangier and Pocomoke Sounds.

The protection afforded in this manner would, however, be but temporary, the demand for oysters constantly increasing, and the number of vessels working liable to increase with it; consequently it may soon be necessary to legislate for the direct protection of the beds and to limit the supply by law before it is stopped entirely by nature. It is well, therefore, for the best interests of all classes, that such an amount of information should be collected, as to the character of the beds and oysters and the general conditions under which they advantageously live, as would direct protective laws into a channel productive of most good.

The first necessary information to be obtained, and that of greatest moment, would be a knowledge of the positions and areas of the beds. No law could be passed which would protect a bed whose position and boundary was not at least approximately known, nor could any study of separate beds or comparisons of many be undertaken without such knowledge. Again, since nature has already selected these areas as those most favorable to the growth and life of the oyster, they evidently are the best grounds upon which to deposit the young brood, should the experiments of Dr. Brooks prove successful and of practical importance. Indeed, it is hardly possible to enumerate all the advantages of knowing the positions and areas of the natural beds, and it may safely be said that a thorough study of the oyster question would be impossible without it.

Of next importance is the knowledge when the bed is in the condition of greatest fecundity.

In the attempt to attain this knowledge the number of oysters to the square yard of the surface was ascertained during the season of 1878, as described by me in my previous report. The results were of comparative value, and subsequent operations in each year were to show whether the oysters on the bed were increasing or diminishing; or, in other words, the fecundity of the bed, as compared with previous seasons, was to be ascertained.

During the last season these numbers have been again calculated in a similar manner; but, working with a greater knowledge of the subject generally, and a more correct estimate of the desired results, I have devised another method for ascertaining whether the bed is in its most productive condition.

It is evident that in any large community there must be a certain ratio between the individuals of different ages, and that any change in this ratio will indicate an increased or decreased fecundity. It was not, and probably will not be for some time, possible to separate the oysters into classes by ages, except in a very rude manner. The only indication of the age is the size of the animal, and the oysters were, therefore, separated into four classes, according to size, in the following manner:

The first class contained all those over three inches in length, and embraced all full-grown, mature oysters.

The second class contained oysters between 2 and 3 inches in length, and these were supposed to be mature and fit for market, and between two and three years of age.

The third class contained oysters between three-quarters of an inch and 2 inches long, and represented the young growth of the preceding seasons, being thus oysters from six months to two years of age.

The fourth class contained all oysters under three-quarters of an inch in length, embracing the most minute that could be recognized, and represented the young growth of the last spawning season, or those of less than a year's growth.

By obtaining a sufficient number of each class from each bed it was intended to establish ratios between each class, which, compared with ratios on new and comparatively unworked beds, would show whether the particular locality under examination was in a state of greatest productiveness or not, and by comparing the ratios of successive seasons, the increase or decrease, constant or otherwise, could be ascertained, and the yield of the bed in ensuing seasons predicted.

In order to have another and more correct standard for comparison and to arrive at certain conclusions as to whether the spatting in any season was general and extending to all beds, or confined to particular localities, and in order to know accurately the number of oysters surviving each period of their perceptive existence, numbers of spat collectors were deposited upon the different beds. It was the intention to frequently inspect these tiles, and by counting the number of oysters on each tile at each examination the number of oysters surviving would be ascertained and the age of the previously-established classes would be decided. Thus the life of a community of oysters, free from the dredging influence and protected from all but natural enemies, would be before us from the time of the first attachment until they reached maturity.

The study of their embryo life properly belongs to the zoological student, and the method of propagation and the successive stages of that life must be left to him to determine. It is valuable to the inquiry under consideration, but not essential; as it is evident that we may neglect the early stages of life and yet arrive at correct conclusions as to the number of mature oysters necessary to support the beds in their best condition.

Next in importance to the knowledge of the absolute fecundity of the bed is a knowledge of those conditions which would influence it, and in order that no cause for the deterioration should be neglected, and that all information bearing in any way upon the propagation and growth of the oyster might be collected, several matters of secondary importance have been subjected to investigation and the results embodied in either this or my previous report.

Included under this head are—

Investigations into the temperatures and the influence of increased or diminished temperature upon the mature oyster and embryo.

Investigations into the character of the water, especially as regards its increased or diminished density.

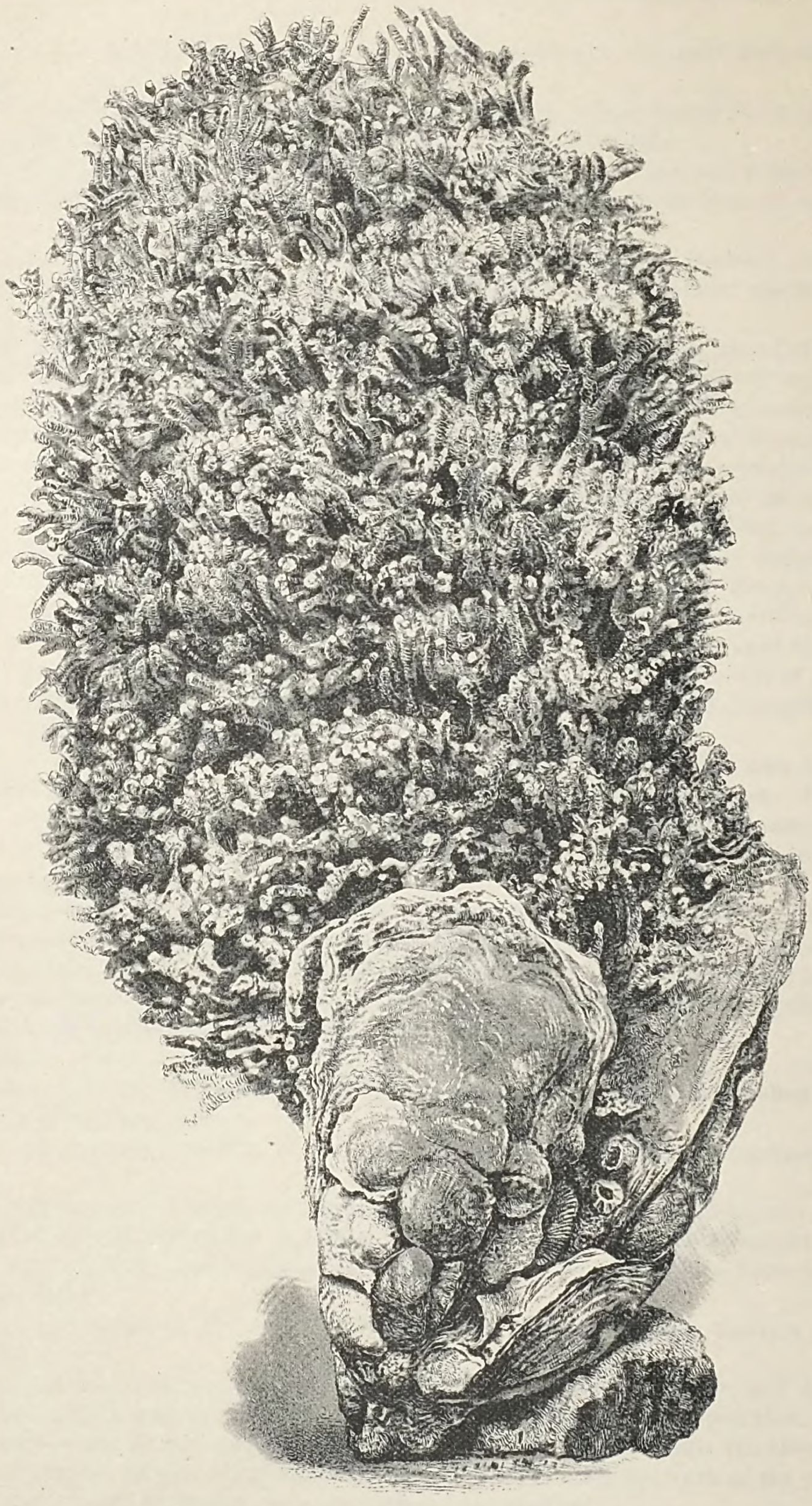
Investigations into the character of the bottom and its influence upon the oyster.

A determination of the direction and velocity of the currents and such collection of statistics of the oyster trade and fishery as would show its present condition and give a value to the dredging factor; and, lastly:

A collection and study of the *fauna* of the beds, particularly of those animals supposed to affect the oyster.

An attempt has also been made to collect the experience of the oystermen and dealers as to the habits of the oysters, and as to the effect of the various changes of environment.

Having shown what, in my opinion, were the objects to be obtained and the direction which the investigation should pursue, it remains now to describe in detail the work of the party in each branch of the inquiry and to decide upon the value of the results.



CLUSTER OF OYSTERS AND SPONGE.
From unworked beds, Chesapeake Bay.
Scale 2/3 Natural Size.

A.Hoen & Co.Lithocaustic,Baltimore.

### DELINEATION OF THE BEDS.

The beds in Tangier and Pocomoke Sounds were surveyed during the season of 1878 and described in my report of the operations of the party during that year. During the last season the survey of the beds has been but an incidental part of the work, only such having been delineated as time and circumstances would permit, though those lying inside the Sounds have been subjected to an examination and survey similar to that of the previous season.

### BEDS IN THE NANTICOKE RIVER.

These are small and inconsiderable, embracing a total area of 827,000 square yards.

Most of them lie on the eastern side of the channel and extend a short distance above Ragged Point, though detached groups may be found much further up the river. The oysters and shells are uniformly spread over each surface. Each bed is very hard, and in most cases the probe would not penetrate beyond six inches, but when it was possible to push through the surface stratum a substratum was found of sand. The main part of the river bottom is of mud, and bottom of that description surrounds the beds. Along both shores the mud is firmer and of greater consistency than in the channel, and above Roaring Point on those bottoms are placed large numbers of oysters transplanted from the Middle Ground Bed and from other localities.

The river seems to be a favorite planting ground, and numbers of boats and canoes were working the Middle Ground Bed during the summer in order to obtain the "plants."

The oysters are small, single and in small clusters, and not of very good quality.

The water being shoal, from 5 to 10 feet, no dredging could be done on these beds, and consequently the number to the square yard has not been calculated.

### BEDS IN THE LITTLE ANNEMESSEX.

There are only a few small beds in this river, and they are very seldom worked. Their total area is 464,000 square yards. The oysters are in detached groups, separated by spaces of mud and sand, and are small, single and in small clusters. The depth of water varies from 6 to 12 feet.

### BEDS IN KEDGE'S STRAIT.

The bottom of Kedge's Strait, from the sands on one shore to those on the other, is covered with scattered oysters to greater or less extent, but they are found in greater numbers in the channel on the soft bottoms than elsewhere. The total area of the beds is 2,894,000 square yards, and three of the beds are of considerable size.

The first lies on the northward side of the Strait, north of Solomon's Lump Light-House, south and southwest of the Western Islands. It extends in a WNW. and ESE. direction (that of the channel), and is 1¼ miles long and from one-eighth to one-half mile broad, and is irregular in outline. Its area is 1,244,000 square yards.

Due west of this bed, south of Oyster Creek and NNW. of Fog Point, is the second bed. It extends north and south five-eighths of a mile, and east and west one-third of a mile. Its area is 646,000 square yards.

Southwest and west from this bed, and northwest from Fog Point, in the middle of the Strait and west of the shoals, is the third bed. Its area is 550,000 square yards, and its greatest length NNW. and SSE. is three-fourths of a mile, with an average breadth of one-fourth of a mile.

The depth of water on the inner bed is from 12 to 16 feet, and on the two outer ones from 14 to 19 feet.

The oysters are spread in groups of different areas, separated by spaces of mud and sand, generally the latter, except close to the channel-way, where there is more mud. The beds are in almost all cases very hard; when the probe would penetrate, soft sand was found. The inner bed is much softer than the other two, and has a larger amount of mud. The oysters were small and dark, single and in small clusters of three or four, with no red sponge or grass. On the outer beds the shells were larger and cleaner than on the inner, and generally the oysters in the Strait are larger and with sharper bills than those inside.

### INVESTIGATION OF THE CHESAPEAKE BAY WEST OF TANGIER AND SMITH'S ISLANDS.

The only information that could be obtained with regard to the ground outside the Sounds was that there were a number of beds of different areas lying in the Bay, on the eastern side of the ship channel, especially about and on the shoals off Smith's Island and Kedge's Strait.

The ground being so little known, and the accurate delineation of the beds being so difficult when attempted with a sailing vessel, I considered it better to employ the limited time at my disposal in running tentative lines, off and on shore, and other lines crossing them, with a view to discover the location of the beds and to mark these localities for a more thorough and exhaustive investigation in the future.

In accordance with this plan I dredged over the bottom of the Bay, from Tangier Island northward, running the lines sufficiently close to detect any beds of importance or the presence of scattered oysters. The distance over which the dredge was dragged was always measured; and, when the depth of water was not too great, the bottom was probed with a view of determining whether it was suitable for the oysters.

By reference to the projections it will be seen that these areas occur quite frequently on the shoal ground making off in a southwesterly direction from Tangier Island; that between Tangier Island and Cheesman's Islands there are, in the deep water, no oysters; and that from abreast Cheesman's Islands as far north as the investigation extended were found large areas upon which oysters were living, and in some cases in great numbers. The depth of water does not appear to influence the formation or growth of these beds, some of them lying on the shoals and others in deeper water. Generally speaking, here as in the Sounds, the original beds were formed on the side of the shoals, and wherever there was a sudden change of bottom.

Wherever the solid beds or "Rocks" were encountered, they were found to be long and narrow ridges, extending generally in a northerly and southerly direction, except when near Kedge's Strait, where they ran more to the eastward and westward; and we could, in standing across the beds, but rarely obtain more than one or two hauls of the dredge before we were off the "Rock." The major axis appears here, as elsewhere, to lie in the direction of the current, and probably all natural extension and growth of any bed are in that direction, the spat being carried backward and forward by the ebb and flow of the tides. The large number of beds near and off Kedge's Strait is probably due to the large number of spat brought out from the Sounds through the Strait.

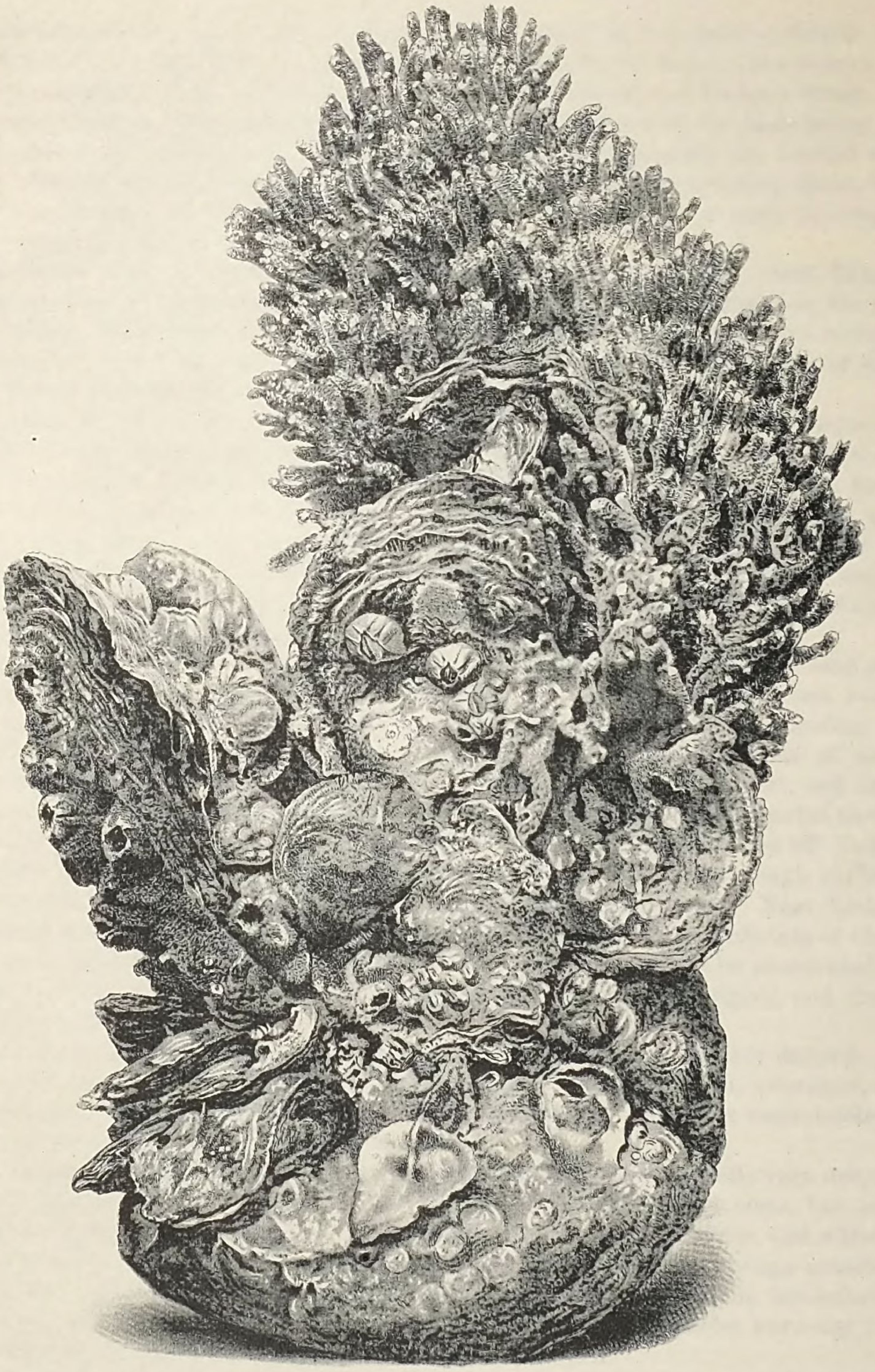
The bottom is generally of hard sand covered with sponge and grass. Near Kedge's Strait some mud sloughs were found, and in some cases the substratum of the beds was of clay; but in most of them the stratum of oysters and shells was too thick and hard to be penetrated.

The beds outside the Sounds have been comparatively free from dredging, and thus present marked differences from those inside.

They are comparatively longer and narrower, and much more sharply defined. Very few scattered oysters are found near them, and the beds are much more solid, unbroken, and much harder, requiring heavier dredges than those used in the Sounds. The most remarkable difference is, however, in the shape and growth of the oysters.

On the undredged beds they are long and narrow, with the lower shells very deep, and bills very thin and sharp. In no case did we find any single oysters of any class, but all grew in clusters of from three and four to twelve and fifteen. The shells were clean and white, and free from mud and sand. Generally there was found a tuft of red or white sponge attached to the clusters, and the mature first and second class oysters were covered and the interstices between them filled with those of the third and fourth classes; numbers of barnacles were also found, and some *crepidula*, but *tubicola* were present only in small numbers.

The oysters found upon beds that have been much worked differ materially, being single and broader in comparison to their length, round and with blunt bills. They are usually dark in color, and have a considerable amount of mud and sand on the shells. The sponges do not appear to be as abundant, and the amount of dredging on any bed may always be known by the appearance of the oysters brought up. Upon an overdredged and almost exhausted bed the oysters will be large and single, blunt-billed, with dirty shells, and with an almost entire absence of sponges, barnacles, and *crepidula;* but the shells will be covered with *tubicola* and bored in many places by the *boring pholad.*



CLUSTER OF OYSTERS AND SPONGE.
From unworked beds, Chesapeake Bay.
Natural Size.

A.Hoen & Co.Lithocaustic.Baltimore.

Late in the last spring the dredgers began working on the beds immediately off Kedge's Strait and the one off Hog Neck, and during the present season the returns show that the beds in the Sounds have been, to some extent, abandoned for those outside in the bay. As so little dredging was done before my examination, I think the results of the dredging operations of the party may be considered as obtained from unworked beds. These results will be alluded to subsequently.

Probably small beds will be found along the shores of the islands from Kedge's Strait to the entrance of Tangier Sound, but as the water was shoal we could not dredge very close in. As far as can be seen at present there is no reason why the existing beds should not be extended very considerably, and such extension will probably take place now that the dredgers are beginning to work upon them. If suitable "cultch" is exposed, probably very large areas will soon be covered with oysters.

*Table showing number of oysters to square yard.*

| Locality. | Number of observations. | Number. |
|---|---|---|
| Section 1, west of Kedge's Strait | 40 | 0.37 |
| Section 2, west of Red House | 7 | 0.44 |
| Section 3, west of White House | 11 | 0.30 |
| Section 4, west of Hog Neck | 28 | 0.40 |
| Mean of observations | | 0.38 |

The above table of the number of oysters to the square yard has been compiled from all observations made in the bay where there was any evidence of a bed existing, such evidence being given by the probe, soundings, and character of the matter brought up by the dredge.

The numbers to the square yard have been calculated in a manner similar to that described in my previous report, and are, as was pointed out in that report, only of value as forming a standard for comparison. It must be borne in mind, however, in making such comparison, that the hardness of the unworked beds and the closeness of the growth of the oysters would prevent as many being taken by the dredge as on the softer and more open beds in the Sounds.

By referring to the table, it will be seen that the number calculated for each locality is very nearly the same as that arrived at by combining all the observations, and that this number is about 0.4 to the square yard. Accepting that as the standard, the number to the square yard upon a bed which has been dredged for some time should certainly not fall below 0.4, and considering the different characters of the bottom, the number, as shown by the dredge, upon an old bed, should be much larger, unless the bed has been overworked.

The following table shows the number of oysters of each class examined, and also the number of bushels brought up and the percentage of shells and *débris* to the whole amount. As will be seen by the table, the number of the fourth class of this year's growth is very large, showing that however bad the season may have been inside the Sounds it has not influenced the reproduction in the bay.

TABLE I.—*Dredging results—Chesapeake Bay.*

| Number of section. | Locality. | Number of hauls of the dredge. | First class. | | | Second class. | | | Third class. | | | Fourth class.* | Number of bushels dredged. | | | | Number of first-class oysters to the bushel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Oysters. | Bushels. | Ratios. | Oysters. | Bushels. | Ratios. | Oysters. | Bushels. | Ratios. | | Total amount. | Bushels oysters. | Bushels débris. | Ratio débris. | |
| 1 | West of Kedge's Strait | 52 | 1,018 | 8.8 | 1.49 | 1,622 | 4.7 | 0.17 | 1,150 | 2.6 | 2.32 | 2,674 | 23.7 | 16.1 | 7.6 | 0.32 | 115 |
| 2 | West of Red House | 12 | 359 | 3.0 | 1.00 | 360 | 1.0 | 0.88 | 318 | 0.7 | 1.41 | 447 | 7.2 | 4.7 | 2.5 | 0.34 | 115 |
| 3 | West of White House | 15 | 135 | 1.1 | 1.07 | 145 | 0.4 | 0.16 | 23 | ..... | 2.15 | 50 | 3.0 | 1.5 | 1.5 | 0.50 | 115 |
| 4 | Hog Neck Rock | 106 | 1,997 | 17.3 | 1.29 | 2,579 | 7.5 | 1.08 | 2,779 | 6.4 | 1.87 | 5,200 | 42.2 | 31.2 | 11.0 | 0.26 | 115 |
| 5 | West of Tangier Island | 15 | 37 | 0.3 | 1.30 | 48 | 0.1 | 1.06 | 51 | 0.1 | 3.74 | 191 | 2.2 | 0.5 | 1.7 | 0.77 | 115 |
| | | 200 | 3,546 | 30.5 | 6.15 | 4,754 | 13.7 | 3.87 | 4,321 | 9.8 | 11.49 | 8,562 | 78.3 | 54.0 | 24.3 | 0.31 | |
| | Mean of ratios | | | | 1.23 | | | 0.78 | | | 2.29 | | | | | | |

*75 per cent of this year's growth.

In the foregoing table the ground dredged over has been divided into parallel sections, and all oysters from the beds in those sections have been assembled together.

Section 1 includes all the beds west of Kedge's Strait.

Section 2 the beds west of that position on the chart marked Red House.

Section 3 the beds west of that position marked White House.

Section 4 the beds west of Hog Neck and Cheesman's Island, and section 5 the beds west of Tangier Island.

In compiling the tables I have entered only those hauls of dredge that have been taken on the beds or where the oysters were in considerable numbers. The scattered and detached groups and single oysters have not been considered. Section 5 is not an important one, owing to the very small areas of all the beds encountered on it.

By examining this table it will be seen that a total of 54 bushels, amounting to 21,183 oysters, were examined; that from 200 hauls of the dredge we obtained 78.3 bushels of oysters and shells, and that 31 per cent. or 24.3 bushels of this matter consisted of shells or other *débris*, and this percentage does not differ materially from that found on each section.

Section 5 is not considered, as the percentage there does not entirely represent shells and other *débris* of the bed, but rather the sponge and grass of the sand shoals.

Regarding these beds as in their natural condition of healthy life, it is inferred from the deduced table that, other things being equal, a larger percentage of *débris* would indicate that the bed was not giving, for the same amount of labor, its natural return; or, in other words, that the mass of old shells brought up by the dredge was out of proportion to the number of oysters. This percentage is of value as indicating the most profitable working grounds, and also as indicating, when very large, that the bed has been overworked and its population destroyed, as the percentage of shells bears the same relation to the oysters as the unoccupied dwellings in a city do to its inhabitants; an increased percentage means a decreased population.

It is evident that there should be a certain ratio between the oysters of different ages, and in general terms the number of young should exceed the mature, thus allowing for the natural depletion in each period of growth. Our present knowledge, however, is not sufficient to allow the assignment of exact values to this ratio, and the ratios between the different classes are too irregular, owing to the variations in the spawnings in the several seasons, to allow their acceptance as a standard. One thing, however, may be assumed as an axiom, and that is, that the number of young growth on a bed should always exceed the mature oysters, for if there are no young oysters in the community there will soon be no old ones, and as there is a constant depletion of each class, the young must sufficiently outnumber the old to allow those ravages and still adequately supply the demand and fill up the vacant places in the higher classes.

An inspection of Table I will show—

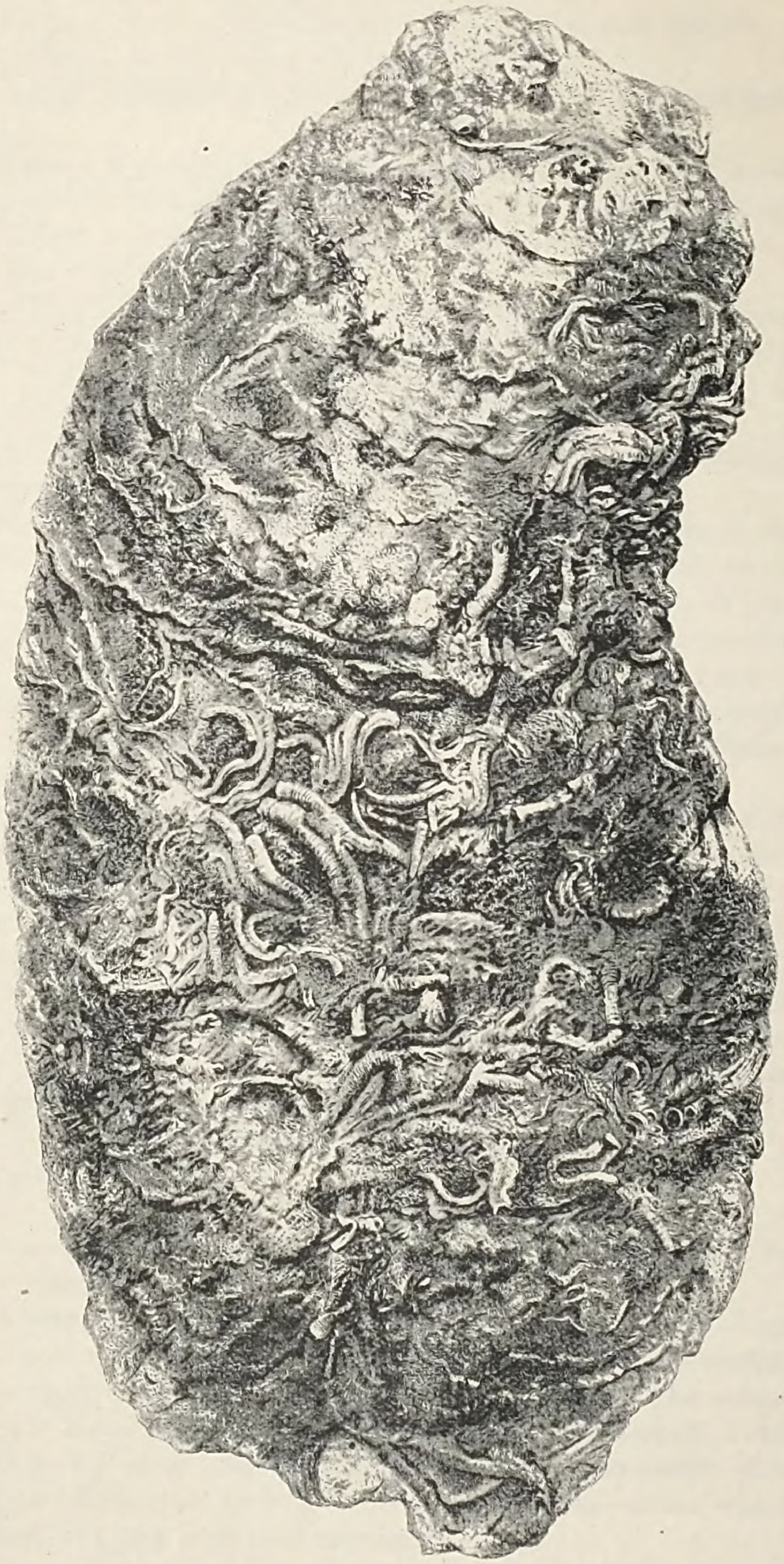
1st. That 75 per cent. of the fourth class were of this year's growth.

2d. That the ratio between the third and fourth classes is the largest, and between the second and third classes the smallest.

As the second class represents oysters of between two and three years of age, and as the ratio between the second and first classes is large, I judge that there was a successful spatting on these beds in 1876; and as the third class represents, on the whole, oysters of the season of 1877 and 1878, and as the ratios between those of that class and those of the second is small, I infer that the seasons of 1877-'78 were bad spawning ones. Again, the fourth class is principally of this year's growth, and the ratio of fourth to third class is large, from which I infer—what was the case—that the spatting of the last season on these beds was successful.

As already explained, the third and fourth classes practically represent the offspring of three successive spatting seasons, and thus contain the young growth on the bed, while the first and second classes represent the mature oysters. If, then, we compare the mature with the young, we have at once a sure indication of the state of the bed so far as its fecundity is concerned.

In order that the areas under consideration might be as similar as possible to the extensive



ADULT OYSTER–NATURAL SIZE
From Bird Bed, Pocomoke Sound.

*A. Hoen & Co. Lithocaustic Baltimore.*

beds inside the Sounds, I have only used for the following table the largest three sections—Nos. 1, 2, and 4:

TABLE II.—*Dredging results—Chesapeake Bay.*

| Number of section. | Locality. | Oysters. |  | Ratios. |
|---|---|---|---|---|
|  |  | First and second classes. | Third and fourth classes. |  |
| 1 | West of Kedge's Strait | 2, 640 | 3, 824 | 1. 06 |
| 2 | West of Red House | 719 | 765 | 1. 06 |
| 4 | Hog Neck Bed | 4, 576 | 7, 979 | 1. 70 |
|  |  | 7, 935 | 12, 568 |  |
|  | Mean of ratios | ........ | ........ | 1. 58 |

Accepting this mean ratio of all young growth to mature oysters, upon comparatively unworked beds, as the standard, it is inferred that the ratio on any bed should not fall below 1.5 or 1.6.

### FECUNDITY OF THE BEDS IN THE SOUNDS.

In order to ascertain whether the fecundity of the beds in the Sounds was the same as that of those outside in the bay, a very thorough dredging was continued during the summer and autumn, and the oysters classified according to the plan already described, and the results are assembled in the following table:

TABLE I.—*Dredging results—Tangier Sound.*

| Locality. | Number of hauls of dredge. | First class. |  |  | Second class. |  |  | Third class. |  |  | Fourth class. | Bushels dredged. |  |  |  | Number of first-class oysters to a bushel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Total amount. | Bushels oysters. | Bushels débris. | Ratio débris. |  |
| Middle Ground Nanticoke. | 1 | 17 | ...... | 5. 18 | 88 | ........ | 1. 06 | 93 | ...... | 0. 43 | 40 | ........ | ...... | ...... | ...... |  |
| Shark s Fin | 57 | 382 | 2. 9 | 1. 28 | 489 | 2. 3 | 0. 92 | 453 | 1. 6 | 0. 92 | 418 | 10. 25 | 6. 8 | 9. 4 | 0. 58 | 246 |
| Were Point | 54 | 340 |  | 0. 91 | 311 |  | 0. 77 | 241 |  | 0. 59 | 142 | 6. 0 |  |  |  |  |
|  |  | 722 |  |  | 800 |  |  | 694 |  |  | 560 | 16. 25 |  |  |  |  |
| Tyler's Bed | 14 | 102 | 0. 5 | 1. 45 | 148 | 0. 4 | 0. 39 | 59 | 0. 2 | 0. 49 | 29 | 3. 50 | 1. 1 | 2. 9 | 0. 72 |  |
| Horsey's Bar | 2 | 15 |  | 1. 06 | 16 |  | 1. 37 | 22 |  | 1. 14 | 25 | 0. 50 |  |  |  |  |
|  |  | 117 |  |  | 164 |  |  | 81 |  |  | 54 | 4. 0 |  |  |  |  |
| Drumming Shoal | 39 | 666 | 3. 0 | 2. 16 | 1, 439 | 4. 2 | 0. 91 | 1, 303 | 3. 0 | 0. 47 | 607 | 12. 5 | 10. 2 | 2. 3 | 0. 18 | 220 |
| Cow and Calf | 6 | 51 | 2. 8 | 0. 66 | 34 | 1. 6 | 0. 68 | 23 | 1. 3 | 1. 06 | 586 | 1. 0 | 5. 7 | 9. 5 | 0. 62 | 162 |
| Grass Tangier | 65 | 417 |  | 1. 25 | 520 |  | 1. 06 | 554 |  |  |  | 14. 25 |  |  |  |  |
|  |  | 468 |  |  | 554 |  |  | 577 |  |  |  | 15. 25 |  |  |  |  |
| Turtle Egg Island | 54 | 375 | 2. 3 | 2. 40 | 900 | 2. 6 | 1. 57 | 1, 419 | 3. 2 | 0. 54 | 770 | 16. 0 | 8. 1 | 7. 9 | 0. 50 |  |
| Mud Bed | 53 | 521 | 3. 2 | 3. 03 | 1, 580 | 4. 6 | 1. 34 | 2, 121 | 4. 9 | 0. 52 | 1, 115 | 21. 0 | 12. 7 | 8. 3 | 0. 40 |  |
| Chain Shoal | 47 | 330 | 1. 6 | 1. 09 | 359 | 1. 0 | 3. 55 | 1, 374 | 3. 1 | 0. 70 | 966 | 21. 0 | 5. 7 | 15. 3 | 0. 72 |  |
| Piney Island Bar | 211 | 1, 282 | 6. 2 | 3. 00 | 3, 850 | 11. 3 | 2. 56 | 9, 857 | 22. 8 | 0. 41 | 4, 070 | 75. 2 | 40. 3 | 34. 9 | 0. 45 | 204 |
| Muscle Hole | 97 | 1, 176 | 7. 2 | 2. 34 | 2, 752 | 8. 0 | 1. 68 | 3, 876 | 9. 0 | 0. 48 | 1, 876 | 45. 0 | 24. 2 | 20. 8 | 0. 46 |  |
| Manokin River | 93 | 881 | 4. 6 | 1. 41 | 1, 282 | 3. 7 | 0. 48 | 2, 158 | 5. 0 | 0. 49 | 1, 169 | 26. 2 | 13. 3 | 12. 9 | 0. 49 | 188 |
| Big Annemessex River | 41 | 392 | 2. 0 | 3. 88 | 1, 521 | 4. 4 | 1. 21 | 1, 846 | 4. 2 | 1. 03 | 1, 905 | 29. 2 | 10. 6 | 18. 6 | 0. 63 | 196 |
| Harris' Bed | 108 | 559 | 2. 7 | 3. 11 | 1, 740 | 5. 1 | 2. 97 | 5, 174 | 11. 9 | 0. 62 | 3, 204 | 21. 0 | 19. 7 | 1. 3 | 0. 06 |  |
| Terrapin Sands | 54 | 426 | 2. 8 | 2. 26 | 996 | 2. 8 | 2. 18 | 2, 110 | 4. 8 | 0. 61 | 1, 292 | 26. 0 | 6. 4 | 19. 6 | 0. 75 |  |
| Jane's Island | 17 | 150 | 0. 8 | 4. 23 | 784 | 2. 3 | 3. 53 | 2, 771 | 6. 4 | 0. 43 | 1, 209 | 14. 5 | 9. 5 | 5. 0 | 0. 34 |  |
| Woman's Marsh | 127 | 852 | 7 4 | 1. 13 | 968 | 2. 8 | 2. 30 | 2, 229 | 5. 1 | 0. 42 | 947 | 65. 0 | 15. 3 | 49. 7 | 0. 76 | 115 |
| Great Bed | 152 | 1, 408 | 8. 0 | 1. 89 | 2, 665 | 7. 8 | 3. 02 | 8, 056 | 18. 6 | 0. 51 | 4, 153 | 116. 5 | 34. 4 | 82. 1 | 0. 70 | 176 |
| Little Thoroughfare | 35 | 82 | 2. 2 | 2. 32 | 190 | 1. 8 | 3. 69 | 702 | 10. 9 | 0. 49 | 346 | 6. 5 | 14. 9 | 7. 6 | 0. 33 | 140 |
| Great Thoroughfare | 33 | 230 |  | 1. 90 | 438 |  | 9. 15 | 4, 010 |  | 0. 36 | 1, 483 | 16. 0 |  |  |  |  |
|  |  | 312 |  |  | 628 |  |  | 4, 712 |  |  | 1. 829 | 22. 5 |  |  |  |  |
| California Bed | 82 | 663 | 3. 3 | 0. 93 | 620 | 1. 8 | 1. 75 | 1, 085 | 2. 5 | 0. 71 | 767 | 24. 0 | 7. 6 | 16. 4 | 0. 68 | 196 |

TABLE I.—*Dredging results—Tangier Sound.*—Continued.

| Locality. | Number of hauls of dredge. | First class. | | | Second class. | | | Third class. | | | Fourth class. | Bushels dredged. | | | | Number of first-class oysters to a bushel. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Number of bushels. | Ratios. | Number of oysters. | Total amount. | Bushels oysters. | Bushels débris. | Ratio débris. | |
| Johnson's Bed | 18 | 39 | 0.2 | 1.38 | 54 | 0.1 | 1.20 | 65 | 0.1 | 0.92 | 60 | 2.0 | 0.4 | 1.6 | 0.80 | |
| Dog Fish Bed | 32 | 213 | 2.2 | 0.68 | 145 | 0 70 | 1.12 | 163 | 0.4 | 0.65 | 107 | 11.5 | ...... | ...... | ...... | 152 |
| Trevise Bed | 1 | 14 | | 2.14 | 30 | | 1.10 | 33 | | 0.91 | 30 | 1.0 | ...... | ...... | ...... | ...... |
| Shell Bed | 31 | 88 | | 0.42 | 37 | | 0.38 | 14 | | 1.78 | 25 | 31.0 | 3.3 | 33.7 | 0.91 | ...... |
| Flat Bed | 16 | 44 | | 0.81 | 36 | | 0.50 | 18 | | 0.44 | 8 | 5.0 | ...... | ...... | ...... | ...... |
| | | 359 | | 0.69 | 248 | | 0.91 | 228 | | 0.74 | 170 | | | | | |
| Muddy Marsh Bed | 22 | 59 | 0.3 | 0.20 | 12 | 0.03 | 0.75 | 9 | ...... | 1.67 | 15 | 14.2 | 0.3 | 13.9 | 0.97 | ...... |
| Bird Bed | 60 | 237 | 1.2 | 0.19 | 46 | 0.10 | 0.37 | 17 | .... | 3.23 | 55 | 50.0 | 1.3 | 48.7 | 0.97 | 188 |
| Hern Island Bed | 39 | 180 | 1.0 | 0.34 | 61 | 0.20 | 3.62 | 221 | 0.5 | 0.16 | 36 | 23.0 | 1.7 | 21.3 | 0.92 | 178 |
| | | 417 | | 0.26 | 107 | | 2.22 | 238 | | 0.39 | 91 | | | | | |
| Parker's Bed | 22 | 154 | 1.2 | 0.99 | 153 | 0.40 | 5.85 | 895 | 2.0 | 0.33 | 296 | 14.2 | 3.6 | 10.6 | 0.74 | 120 |
| Brig Bed | 23 | 166 | 1.3 | 0.57 | 89 | 0.20 | 1.07 | 95 | 0.2 | 0.52 | 50 | 77.0 | 7.7 | 6.9 | 0.77 | 120 |

By referring to Table I it will be seen that on all the beds in Tangier Sound, from Fishing Bay down to the Great Rock, with one exception, that of Chain Shoal, the maximum ratio is that of the second class to the first. The inference is that there was a successful spatting season on all the upper beds in 1876 or 1877, probably the former.

Again, the minimum ratio, as far down the Sound as the Mud Bed, is that of the third class to the second, showing that on the beds above the Mud Bed there was not a successful attachment in 1878, which was the case as attested by ourselves. The remaining ratios on these beds show that there has been some attachment during the present season.

Leaving the Chain Shoal Bed for the present, the minimum ratio on all the remaining beds is that of the fourth class to the third, showing that there has been but little attachment of young during the season of 1879.

The remaining ratios show that there was a partial attachment of young on the beds between Turtle Egg Island Bed and the Great Rock during 1878, and a partial attachment on the remaining beds north of Jane's Island during 1876 or 1877, while there was a successful spatting on those lower beds during 1878, which conclusion was found to be correct by our observations during that season.

Arranging these deductions in tabular form, we have the following:

*Table showing the success of spatting in different seasons—Tangier Sound.*

| Year. | Section No. 1. | Section No. 2. | Section No. 3. |
|---|---|---|---|
| | Upper Tangier beds down to Mud Rock. | Middle Tangier, Turtle Egg Island, to Great Rock. | Lower Tangier, below Jane's Island. |
| 1876 or 1877 | Successful | Successful | Moderately successful. |
| 1878 | Unsuccessful | Moderately successful | Successful. |
| 1879 | Moderately successful | Unsuccessful | Unsuccessful. |

The Chain Shoal differs from the beds of its section, the upper, in having its successful spatting season in 1878, and its moderately successful one in 1876 or 1877, while during the last season there has been but a small attachment; it thus assimilates itself to Section 3.

If Table I is again referred to for the Pocomoke beds, it will be found by assembling the upper beds under one head and considering the Bird and Hern Island Beds to be, what they practically are, one bed, we have a table for Pocomoke, as follows:

*Table showing the success of spatting in different seasons—Pocomoke Sound.*

| Year. | Upper Pocomoke. | Muddy Marsh. | Bird and Hern Island Beds. | Parker's and Brig Beds. |
|---|---|---|---|---|
| 1876 or '77 | Unsuccessful | Unsuccessful | Unsuccessful | Moderately successful. |
| 1878 | Successful | Moderately successful. | Successful | Successful. |
| 1879 | Moderately successful. | Successful | Moderately successful. | Unsuccessful. |

With regard to these tables, it must be remembered that the success or want of it is only by comparison with previous years, nor does it necessarily mean that there has been even a moderate attachment, but only that one year was better than another.

By combining the first and second classes and third and fourth on each bed, and combining such beds as are similarly situated and contiguous, I have arranged the following table for comparison with the similar one of the dredging results on the beds in the bay:

TABLE II.—*Dredging results—Tangier and Pocomoke Sounds.*

| Name of bed. | Oysters. First and second classes. | Oysters. Third and fourth classes. | Ratio. |
|---|---|---|---|
| Shark's Fin | 871 | 871 | 1. 0 |
| Were Point | 651 | 383 | 0. 58 |
| | 1, 522 | 1, 254 | 0. 82 |
| Tyler's Bed | 250 | 88 | 0. 35 |
| Horsey's Bar | 31 | 47 | 1. 51 |
| | 281 | 135 | 0. 48 |
| Drumming Shoal | 2, 105 | 1, 909 | 0. 90 |
| Cow and Calf | 85 | 23 | 0. 25 |
| Grass Tangier | 937 | 1, 140 | 1. 21 |
| Turtle Egg Island | 1, 275 | 2, 189 | 1. 71 |
| Mud Bed | 2, 101 | 3, 236 | 1. 53 |
| Muscle Hole | 3, 928 | 5, 752 | 1. 46 |
| | 8, 326 | 12, 340 | 1. 48 |
| Chain Shoal | 689 | 2, 340 | 3. 41 |
| Piney Island Bar | 5, 132 | 13, 927 | 2. 71 |
| | 5, 821 | 16, 267 | 2. 79 |
| Manokin River | 2, 163 | 3, 327 | 1. 51 |
| Big Annemessex | 1, 913 | 3, 751 | 1. 96 |
| Harris Bed | 2, 299 | 8, 378 | 3. 64 |
| Terrapin Sands | 1, 392 | 3, 402 | 2. 44 |

| Name of bed. | Oysters. First and second classes. | Oysters. Third and fourth classes. | Ratio. |
|---|---|---|---|
| Jane's Island | 934 | 3, 980 | 4. 26 |
| Great Bed | 4, 073 | 12, 209 | 3. 00 |
| | 5, 007 | 16, 189 | 3. 23 |
| Woman's Marsh | 1, 820 | 3, 176 | 1. 74 |
| Little Thoroughfare | 272 | 1, 048 | 3. 85 |
| Great Thoroughfare | 668 | 5, 493 | 8. 22 |
| California Bed | 1, 283 | 1, 852 | 1. 44 |
| Johnson's Bed | 93 | 125 | 1. 34 |
| | 2, 316 | 8, 518 | 3. 67 |
| Dog Fish Bed | 358 | 270 | 0. 75 |
| Flat Bed | 80 | 26 | 0. 32 |
| Trevise Bed | 44 | 63 | 1. 43 |
| Shell Bed | 125 | 39 | 0. 31 |
| | 607 | 398 | 0. 65 |
| Muddy Marsh | 602 | 24 | 0. 04 |
| Bird Bed | 283 | 72 | 0. 25 |
| Hern Island Bed | 241 | 257 | 1. 07 |
| | 524 | 329 | 0. 62 |
| Parker's Bed | 307 | 1, 191 | 3. 87 |
| Brig Bed | 257 | 145 | 0. 56 |

The ratios underlined thus (........) are the only ones considered, and show the ratio of young growth to mature oysters in each locality.

I find the ratio of young growth to mature oysters to be, generally speaking, a constantly increasing one from the head of Tangier Sound to the last section.

In my report of the investigation carried on in 1878, I called attention to the noticeable absence of "young" on the beds above Piney Island Bar and Kedge's Strait, and to the large attachment on the southern beds, and the ratios in Table II begin increasing materially on those beds where there was a successful attachment of young during the previous season.

Referring to the "Spatting Table," it will be seen that on the upper section there has not been a successful attachment since 1876–'77; hence, the mature oysters from two to three years old, the growth of those seasons, should be in the ascendant naturally, and hence the small ratios on the upper section.

Apparently the ratios should be about the same on the middle section, as its successive spatting season was also in 1876–'77; but the moderately successful season was in 1878, while on the upper section it was in 1879; and as brood oysters are constantly taken from the beds in constantly increasing numbers it follows that the yield of each succeeding year will be less. As an additional cause, more of the beds in the upper section are worked during the summer than in the others.

During the season of 1878 there was an extraordinary growth of young on Harris' bed, which accounts for its large ratio, and the increase of the other ratios over those of the first section is due to some extent to the attachment of the season of 1878.

On the lower section the ratios are very large by reason of the successful attachment in 1878, and the but moderate success of the seasons of 1876–'77.

The variations in the ratios can thus be accounted for by the success or failure of different spatting seasons, and no doubt this success or failure has its influence, but that its effects are not invariable can be seen by reference to the ratios of Pocomoke Sound.

With the exception of Parker's Bed, a small bed lying near Watt's Island and which has not been dredged as extensively as the others in Pocomoke Sound, we find the ratio of young growth to mature oysters exceedingly small. In no case do the former predominate. From this, according to the deductions from the Tangier beds, it would be inferred that the seasons of 1876 or 1877 were unusually successful ones for the attachment of the spat, and that subsequently there has been no successful season.

By referring to the spatting table we find, however, that the spatting season of 1876 or 1877 was on the whole unsuccessful, and the seasons subsequent have either been successful or moderately so, and this conclusion is supported by our observations during 1878. But as the success or non-success as shown by the spatting table is comparative only, we can only assume that whether successful or not the attachment was not sufficient as one explanation of the small ratios found in Pocomoke.

Consequently the variation in the success of different spatting seasons is not sufficient to explain unusual and abnormal changes in the ratios of the young growth to the mature oyster.

It is evident that the removal of a large number of mature oysters from a bed would show apparently an increased fecundity, by increasing the ratio of young growth to mature oysters, and this apparent increase would be observable for at least two years, or until the young growth became in turn mature, when, as the reproduction would naturally be diminished by the removal of the brood oysters and consequently there would be a smaller number of young growth, and as the young growth of the previous year would be in that time mature, the ratio would suddenly turn in the opposite way, and be as abnormally small as it had been abnormally large. Once having taken this turn, and the fishing still continuing, the ratios would constantly decrease. A few fluctuations might occur now and then, but the general tendency would be a diminishing one.

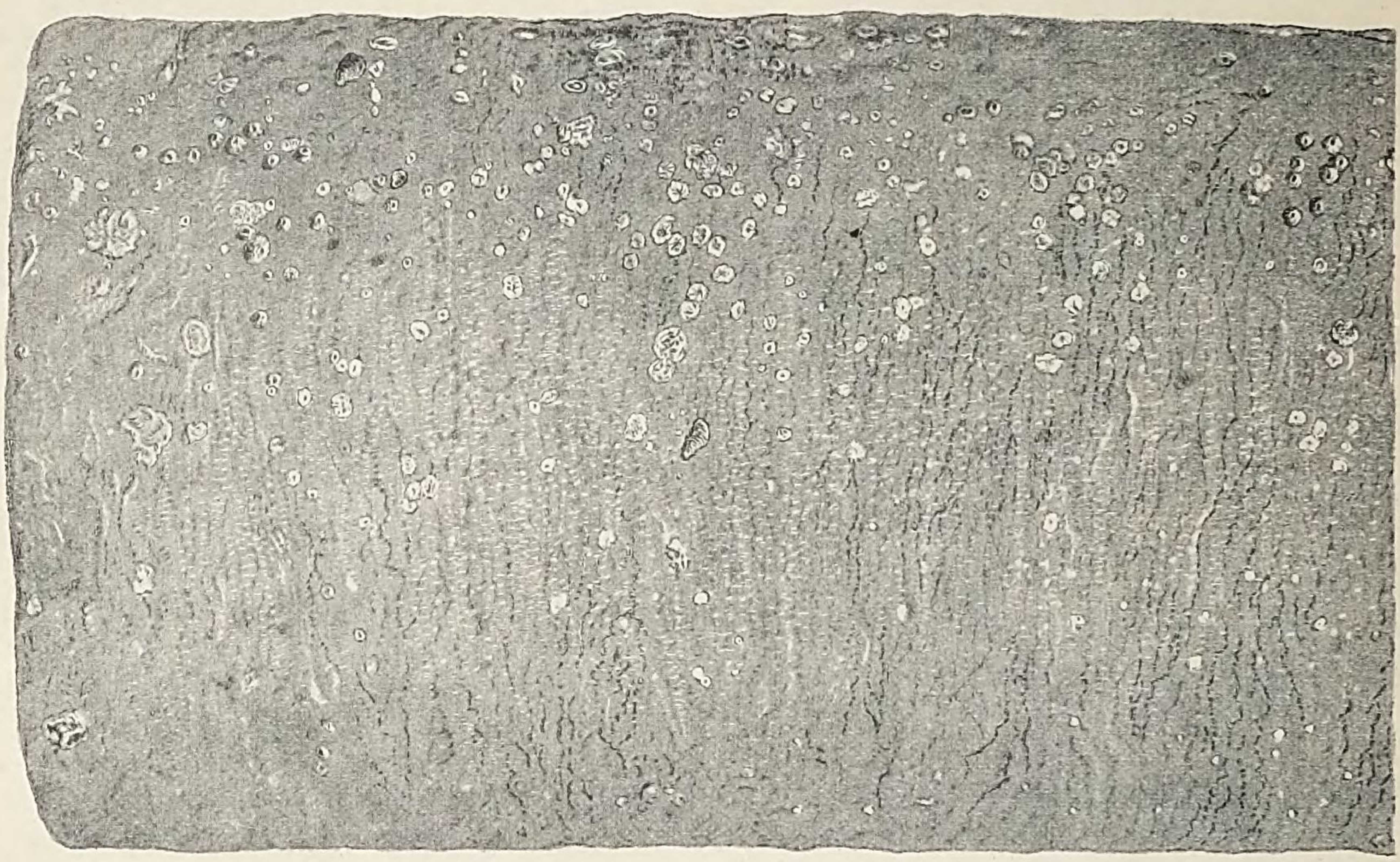
Nature arranges her own laws of supply and demand, and the ratios she establishes between the different classes in any community are most likely to be the necessary ones, and such are the only ones that can be accepted as standards. We have established that upon the unworked beds in the Bay the ratio of young growth to mature oysters is about 1.5, but as this is the result of but one season's observations, and those over a somewhat limited area, it would be rash to accept that standard exactly or to draw rigid inferences from comparison with it. Therefore, in order to allow a sufficient margin for the variations of different seasons and localities, it will be better to consider the normal ratio as between 1 and 2, and consequently any increase or decrease of that ratio will be an indication of diminished fecundity, and, all things remaining the same, the eventual destruction of the beds.

Comparing the ratios of the beds in the Sounds with that established as a standard, we find that—

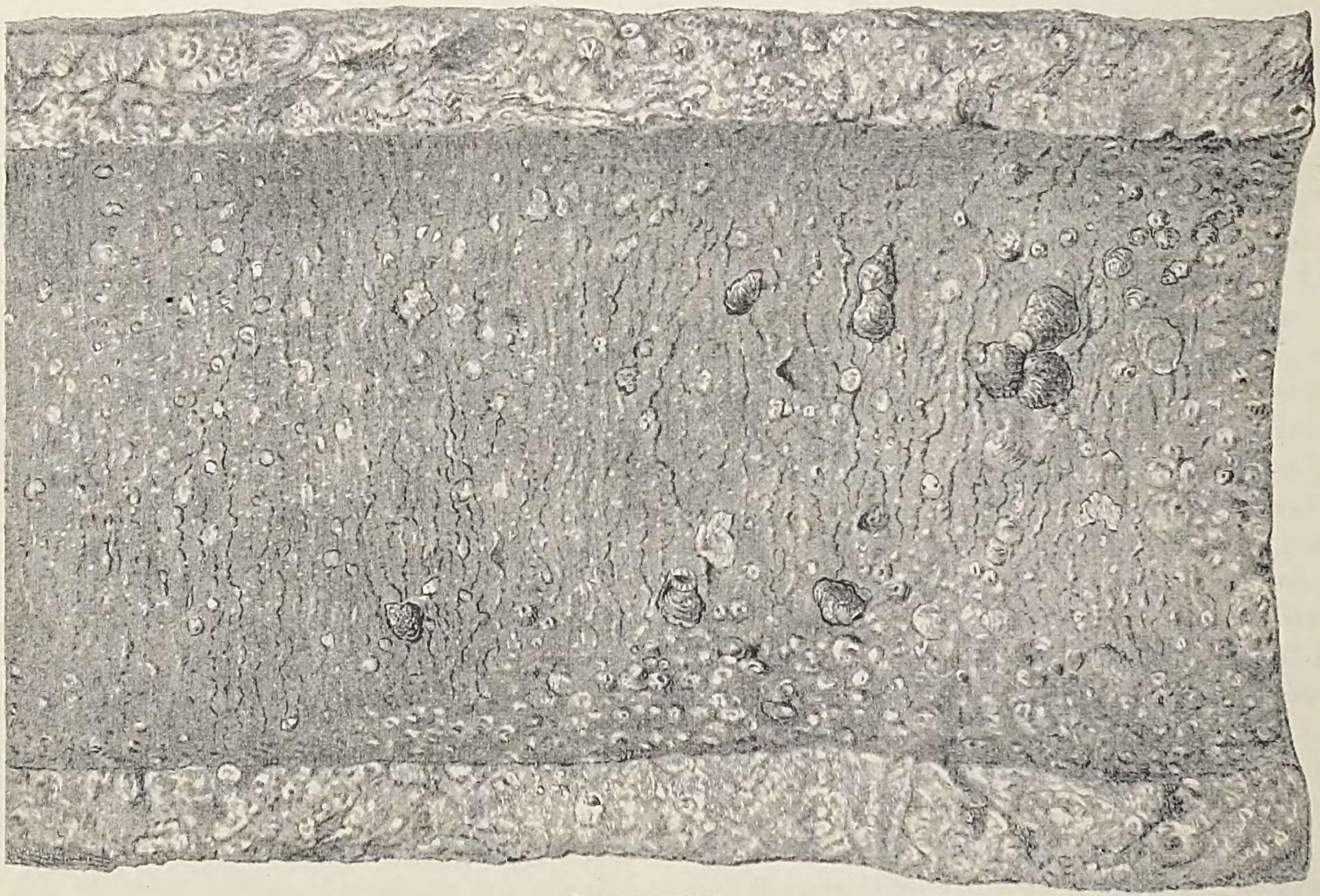
1st. All beds above the Grass Tangier fall below the minimum ratio.

2d. That the groups including Tangier Grass and Muscle Hole are within the limit, as are the beds in the Manokin and Big Annemessex Rivers and the Woman's Marsh Bed.

SPECIMEN TILE No. 7.
Placed in position July 9th Removed August 2nd
Scale 2/3 Natural Size.



Upper Side.



Lower Side.

A.Hoen & Co.Lithocaustic,Baltimore.

3d. That all other groups exceed the maximum ratio.

4th. That all beds in Pocomoke, with the exception of Parker's Bed, are below in minimum.

Instituting another comparison, that of the percentage of *débris* to the total amount brought up, we find that, with the exception of Drumming Shoal, Harris' and Jane's Island Beds, the percentage constantly increases to the southward, and that in Pocomoke it is larger than elsewhere, and larger on the Muddy Marsh and Bird Beds than on any others.

A coincidence will here be noticed in the increased ratios in lower Tangier and the increased percentage of *débris*, and in Pocomoke in the small ratios and very large percentage of *débris*.

*Table showing number of oysters to the square yard.*

TANGIER SOUND.

| Name of bed. | Number of hauls of dredge. | | 1878. | 1879. | Differences. |
|---|---|---|---|---|---|
| | 1878. | 1879. | | | |
| Horsey's Bar | ...... | 6 | ........ | 0.254 | ........... |
| Tyler's Bed | ........ | 12 | ........ | 0.529 | ........... |
| Were Point | 14 | 50 | 1.254 | 0.840 | —.414 |
| Shark's Fin | ........ | 80 | 1.014 | 0.328 | —.686 |
| Drumming Shoal | ....... | 57 | ........ | 0.994 | ........... |
| Tangier Grass | 10 | 100 | 1.064 | 0.372 | —.692 |
| Turtle Egg Island | 13 | 55 | 0.382 | 0.295 | —.087 |
| Mud Bed | ........ | 52 | 0.642 | 0.515 | —.127 |
| Chain Shoal | ........ | 41 | 1.539 | 0.242 | —.296 |
| Piney Island Bar | 49 | 198 | 0.687 | 0.544 | —.143 |
| Muscle Hole | 36 | 87 | 0.826 | 0.746 | —.080 |
| Manokin River | 25 | 90 | 0.134 | 0.320 | +.186 |
| Big Annemessex River | 7 | 41 | 0.560 | 0.665 | +.105 |
| Harris' Bed | 40 | 109 | 0.281 | 0.423 | +.142 |
| Terrapin Sands | 12 | 51 | 0.271 | 0.423 | +.152 |
| Jane's Island | ........ | 14 | ........ | 0.670 | ........... |
| Woman's Marsh | 32 | 110 | 0.240 | 0.125 | —.115 |
| Great Bed | 36 | 151 | 0.165 | 0.265 | +.100 |
| Little Thoroughfare | 9 | 35 | 0.145 | 0.104 | —.040 |
| Great Thoroughfare | 10 | 32 | 0.115 | 0.236 | +.121 |
| California | 36 | 79 | 0.212 | 0.261 | +.049 |
| Johnson's | 4 | 17 | 0.187 | 0.074 | —.113 |

POCOMOKE SOUND.

| Name of bed. | Number of hauls of dredge. | | 1878. | 1879. | Differences. |
|---|---|---|---|---|---|
| | 1878. | 1879. | | | |
| Upper Pocomoke Beds | ........ | 79 | ...... | 0.139 | ........... |
| Muddy Marsh | 3 | 20 | 0.405 | 0.070 | —.335 |
| Bird Bed | 4 | 58 | 0.360 | 0.124 | —.236 |
| Hern Island Bed | 6 | 39 | 0.294 | 0.110 | —.184 |
| Parker's Bed | ........ | 21 | 0.573 | 0.303 | —.270 |
| Brig Bed | ........ | 23 | 0.269 | 0.154 | —.115 |

The number of oysters to the square yard ascertained, as described in my report of the investigation of 1878, has been calculated for each bed, and the results tabulated, together with those of the previous season, for convenience of comparison. Though a standard has been established by the number found on the unworked beds in the bay, no comparison, except in one way, is just, the conditions of bottom and difference of growth upon the worked and unworked beds differing so materially. The number on any bed, obtained by the method we have used, will always be much less than what is really the case, but they will be much less true on an unworked bed than upon one which has been for some time subjected to dredging influences, and where the bottom is soft and yielding, and the oysters grow singly or in small clusters instead of being cemented together and to the surface stratum, as they are on the undredged beds. Therefore, any number obtained from a bed which has been worked should be larger than that obtained from an unworked one. How much so it is impossible to say, but it is evident that a smaller number would indicate a failure of the mature oysters.

In calculating these numbers only first and second class oysters have been considered.

It will be seen by the table that on all the beds above Kedge's Strait there has been a marked decrease in the number of oysters to the square yard. That on the remaining beds, with the exception of Woman's Marsh and Johnson's beds, and considering the Thoroughfare beds as one, there has been an increase in the number of oysters. That on all the beds in Pocomoke Sound there has been a marked decrease.

It will also be seen that on many of the beds the number falls below the standard of 0.4, that on none of them is it very much greater, and that, generally speaking, the numbers are less than the standard on those beds that show a gain upon the number established during 1878.

It would appear, then, by one comparison, that most of the beds have not a sufficient number of mature oysters upon them; and by the other, that however many were taken off, yet nature could more than supply the demand. These inconsistent results may be the result of several causes. The standard may be too high; but, as has been explained, if the beds are in equally good condition, the probability is that the dredge would bring up a larger number from the old than from the new beds. The smallness of the numbers on the lower beds may be due to the greater depth of water and hardness of the bottom, though they do not differ greatly in that respect from the beds in the bay, however much from those in the northern part of the Sound.

It would not be wise to decide hastily, upon the evidence of the numbers to the square yard, that the beds are either deteriorating or the reverse, especially as the comparison has been of but two seasons. If, after they have been continued for some time, there should be an increased number shown, it may be considered differently; but, as all experience testifies to the deterioration of the beds, the inconsistency of the results shown by the table can probably be explained in another way than by assuming the standard number to be too great, and this explanation will be subsequently attempted.

### INFORMATION OBTAINED FROM "SPAT COLLECTORS."

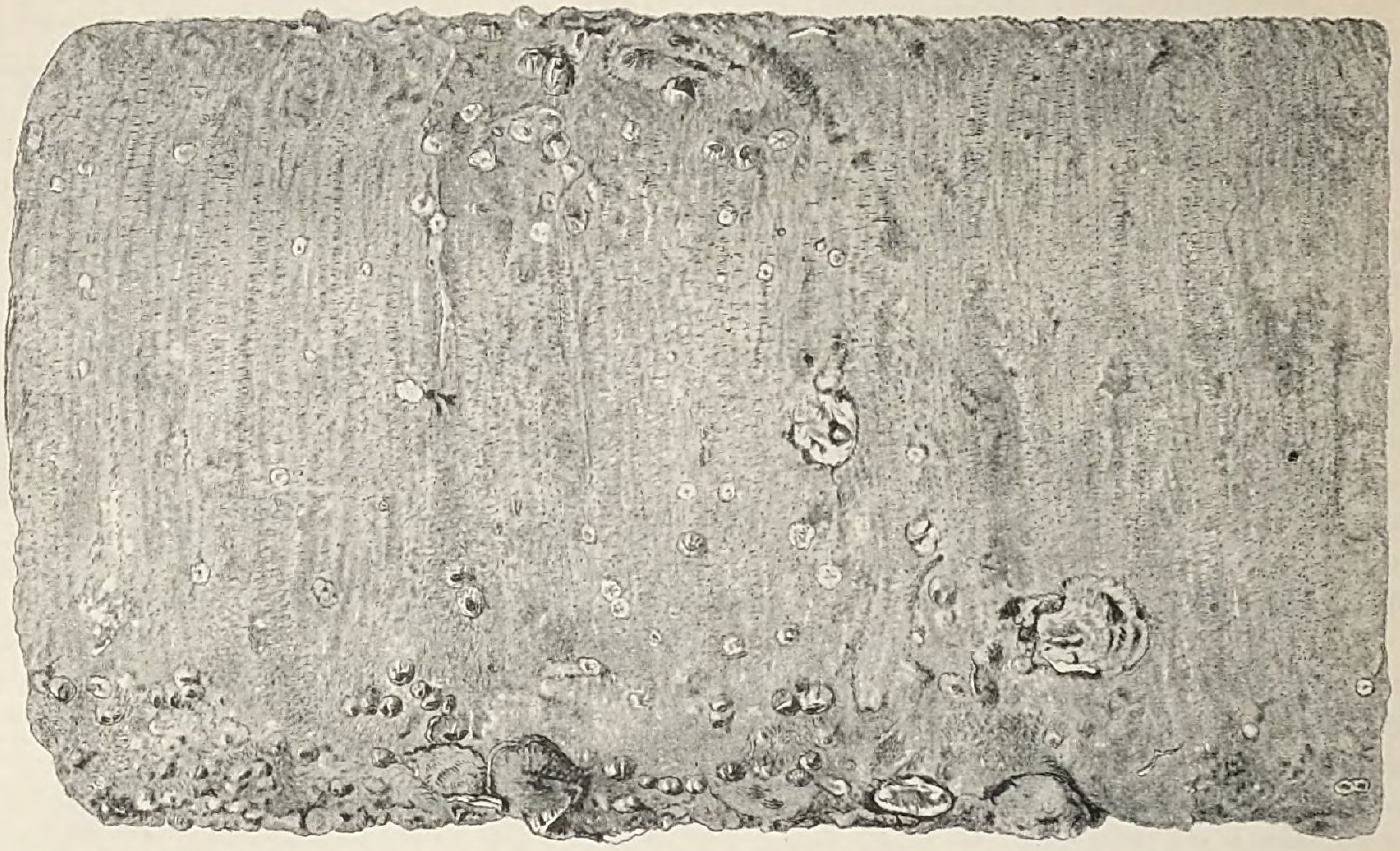
In order to ascertain when the first attachment of young took place on each bed, the comparative extent of such attachment, the influence of bottom and depth of water upon the attachment, and, finally, the increase in size of the oyster and the number surviving each period of their existence, I placed early in July twenty-four spat collectors on the beds in the Sounds; but I regret to say that the collectors were removed by some ill-disposed persons almost as soon as placed.

The last hurdle, as the bundle of tiles was called, was in position on July 14, and on July 15 only four remained in position, and after the 1st of August there was but one left (No. 7, in the Big Annemessex River).

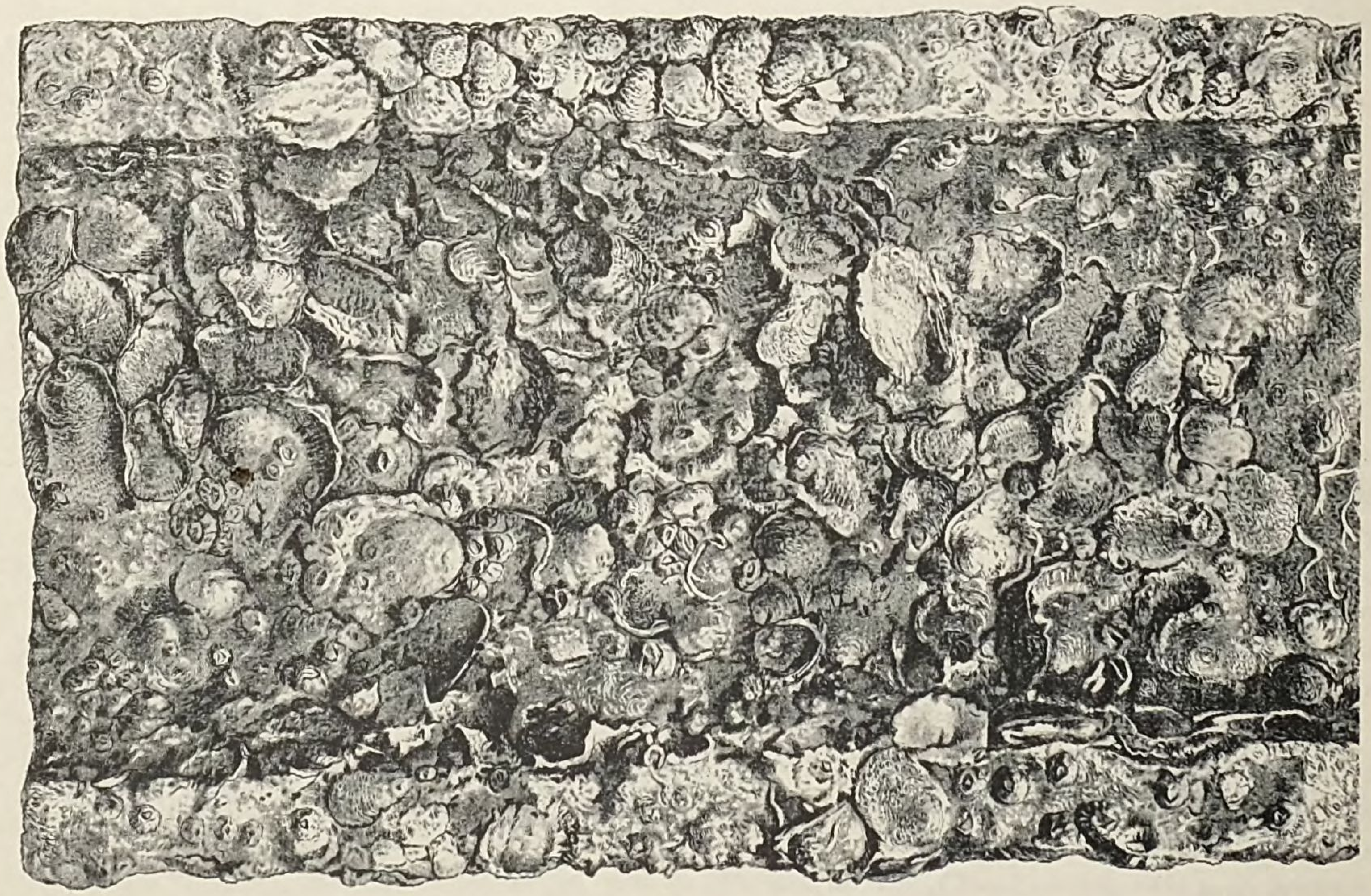
The hurdles were composed of eight or sixteen half-round tiles, lashed on a wooden frame, and so arranged that the frame rested on the bottom, the tiles being thus raised about six inches above the bottom. The tiles were ordinary earthenware ones, unglazed, and were always placed so as to have their concave side underneath. As long as the hurdles remained in position they were frequently examined in order to ascertain the advent of the young brood, and from those examinations I am of the opinion that the first attachment of oysters took place about July 17, as on that day we discovered, with the aid of the microscope, oysters on Hurdle No. 12, on Chain Shoal, and on the 19th, in the same way, found them on No. 7, in the Big Annemessex. On July 24 they were observable on the hurdles on the Great Rock, both in shoal and deep water. Though the attachment probably began about the middle of July, yet it was only evident on the tiles, as our dredging operations did not discover any attachment before the 12th of August, when the young brood were found in moderate numbers on all the beds in both the Sounds.

The number found in Pocomoke Sound was much smaller than in Tangier, and the number on the Upper Pocomoke beds and on the Muddy Marsh bed was smaller than on the lower ones. The attachment appears to be proportional to the number of oysters, such beds as the Muddy Marsh, for instance, having very few young; but as the bed is badly broken up, this may be owing to the absence of proper cultch. The young appear to select the cleanest and smoothest shells for attachment, and we always found that the "boxes," or those shells which had not been separated

SPECIMEN TILE No 2
Placed in position July 9th Removed August 23rd
Scale 2/3 Natural Size.



Upper Side.



Lower Side.

A. Hoen & Co. Lithocaustic, Baltimore.

completely, contained the largest number of young brood. We also found that the size of the young depended, to a great extent, upon the depth of water. Those first detected by us were from two millimeters to one centimeter in length, and as the shoal-water oysters spawn first, and as we found the young of the largest size in shoal water, I infer that the attachment of the oyster occurs very near the location of the parent.

The hurdle in the Big Annemessex was subjected to four examinations. It was placed in position on July 9, and on July 19, when the first examination was made, there were a few oysters on the tiles, but so small that a microscope was necessary in order to recognize them.

The second examination was on August 2, and the oysters were then quite perceptible and easily counted. The total number of oysters on the tiles was then 1,506; deducting those on tile No. 7, which tile was removed, there were 1,177. The number on a tile varied greatly, the maximum being 348 and the minimum 26.

The third examination was on the 23d of August. The oysters had increased very much in size and in numbers. The total number on the tiles was now 1,334, showing an increase of 0.13 per cent. of the number at the second examination. The number on the lower side of the tiles was much larger than on the upper. A tile (No. 2) was removed, and, deducting the number of oysters on it from the sum, there were 1,202 still on the hurdle. A few oysters were injured, probably by raising or lowering the hurdle from and to the bottom.

The fourth examination was on the 10th of October. The total number of oysters was then 539, showing a decrease of 55 per cent. At this examination about two-thirds of the oysters were of the third class, or over three-quarters of an inch in length, and two of them were over two inches long, being thus of the second class. All, however, could be distinguished as of very recent growth, being very long and thin, with thin, delicate shells, easily broken with the thumb-nail or point of a penknife. The largest numbers were still found on the lower sides of the tiles. A moderate number of oysters had been injured by rough handling.

I infer from the four inspections made of this hurdle, and from the one or two made of others before they were removed, that the first attachment of young began, as I have said, about the middle of July, and continued until about the 20th of August, as on the 23d of that month there was no indication of any recent attachment. Probably it reaches its maximum number about the end of July, and decreases afterwards. The mortality after the 23d of August was very great, fully 50 per cent. perishing from some unknown cause, which, though unknown, is certainly natural. We did not notice any evidence of the destructive effects of drills or other animals, though their agency would only be discovered by the evidence of the holes in the upper valves, but as those valves were never present, it cannot be said with certainty that the destruction was not due to them. Whatever the cause, the fact is that 50 per cent. perished in the first six weeks of their existence.

The tiles have shown that the increase in size is much greater than was supposed, and are the first and only authentic evidence upon that point which has been produced with regard to the American oyster. Again, it is conclusively shown by these tiles and some others that were dredged up from the Woman's Marsh beds (Hurdle No. 24), that the greatest attachment is on the lower concave side, and consequently that whatever may be the movements of the embryo oyster before attachment, during the period just prior to it they are near, if not on the bottom, and in seeking their place of attachment they must rise. In this they are similar to the European variety. The selection of the lower sides of the tiles and the interior of the "boxes" may be an effort of nature to provide some protection for the young brood, by, to a certain extent, inducing them to seek dark and secluded points for attachment, or the large number found in such places may be due to the inability of the various enemies of the spat to get at them when thus protected.

It is a matter of very great regret that we have not a large number of specimens and observations for comparison, as all the future investigations in this field would be greatly assisted by an accurate knowledge of the rate of decrease in number and increase in size of the oysters, and it is to be hoped that the hurdle in the Big Annemessex will be allowed to remain in position long enough to permit the meager, yet valuable, information it can produce to be made public.

### INVESTIGATION OF TEMPERATURES.

It was intended that a self-registering thermometer should be placed on each hurdle, and that the temperature to which the young were exposed should be noted at each examination. Fortunately, considering the fate of the hurdles, the thermometers were not received in time to be used as was intended, and after the disappearance of the spat collectors it was not considered advisable to expose the thermometers to the same risks. About the last of July, however, I had the temperature of the surface water recorded every two hours, and considering that there is probably but little variation in the limits of the Sounds, I have plotted the accompanying curve of maximum and minimum temperatures from July 29 to October 1. It will be seen that these curves are very irregular, and that the greatest irregularities occur during the month of August, and that the greatest difference is between the 6th and 10th of August, one of 15° in four days. On the 15th there is a change of 8°, and on the 28th of 12°.

About the 4th of August I determined to utilize the channel buoys as marks for the positions of thermometers, hoping that they might thus escape the observation of those who were inclined to remove them. Accordingly, we placed four self-registering thermometers on the beds; one at the foot of the buoy on the Shark's Fin, one on the buoy on Piney Island Bar, one on the buoy off Watts' Island light-house, and one on the buoy off Syke's Island, about the middle of Pocomoke Sound. We were enabled to make several examinations of these thermometers; but about the 1st of September, finding that one had been stolen, I concluded to remove the others before they shared the same fate.

The curves of maximum and minimum temperature given by these thermometers, and also the range of variation, are shown on the same sheet with the curves of surface temperature.

The thermometers were in place too late, and for too short a period, to allow any safe conclusions to be based upon the information given by them; but it is noticeable, as an interesting coincidence, that the curves of both surface and bottom temperatures show the greatest variations about the time when the young were what is known as "spat," or during the period of and just before attachment; the young on the shoal beds presumably attaching by early August, and those on the deep water or southern beds somewhat later. I regret that it was impossible for me to more thoroughly study the effects of the change of temperature, as I think the failure or success of the spatting, other things being equal, will be found to depend mainly upon the temperature to which the mature oyster and embryos are exposed during the spawning season.

### INVESTIGATION OF THE CHANGES IN DENSITY OF THE WATER.

In order to have definite information as to the change of density of the water surrounding the oysters, and regarding such changes during the spatting season as of most importance, and as the maximum change would be most likely to occur about the time of the spring tides, I determined to obtain specimens of water on a certain number of sections across each Sound at high and low water of the spring tides. The sections were located as follows, and are shown on the sketches accompanying this report:

Section No. 1 was just above Hooper's Strait and at the mouths of the Nanticoke and Wicomico Rivers, in order that the influence of both the strait and rivers might be shown.

Section No. 2, for the same reason, was north of Kedge's Strait and across the mouths of the Manokin and Big Annemessex Rivers.

Section No. 3 was across the entrance of both Sounds, south of Watts' Island.

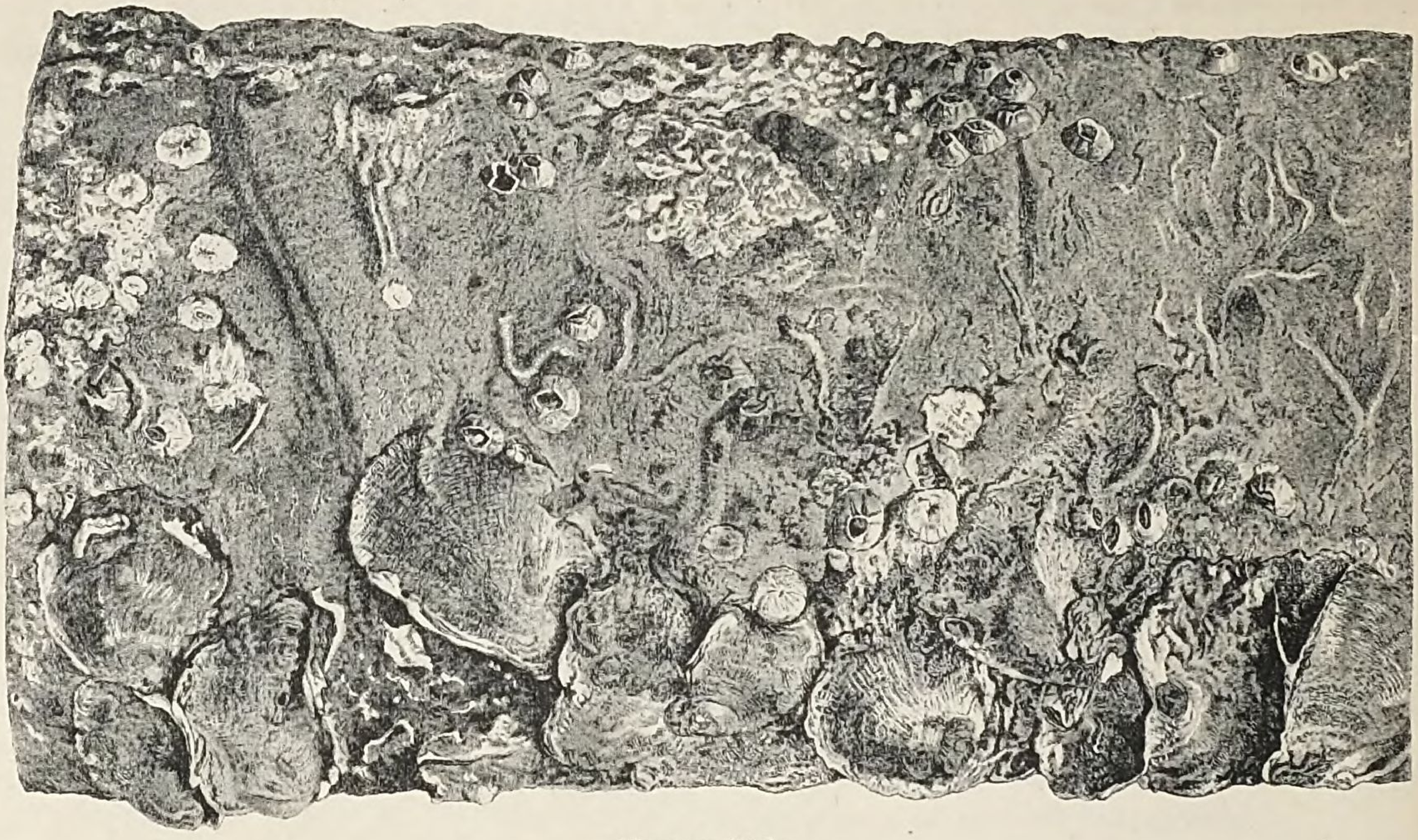
Section No. 4 was across the middle of Pocomoke Sound, that the influence of Guilford and Mesongo Creeks might be known.

Section No. 5 was above the natural beds of Pocomoke Sound and across the mouth of Pocomoke River.

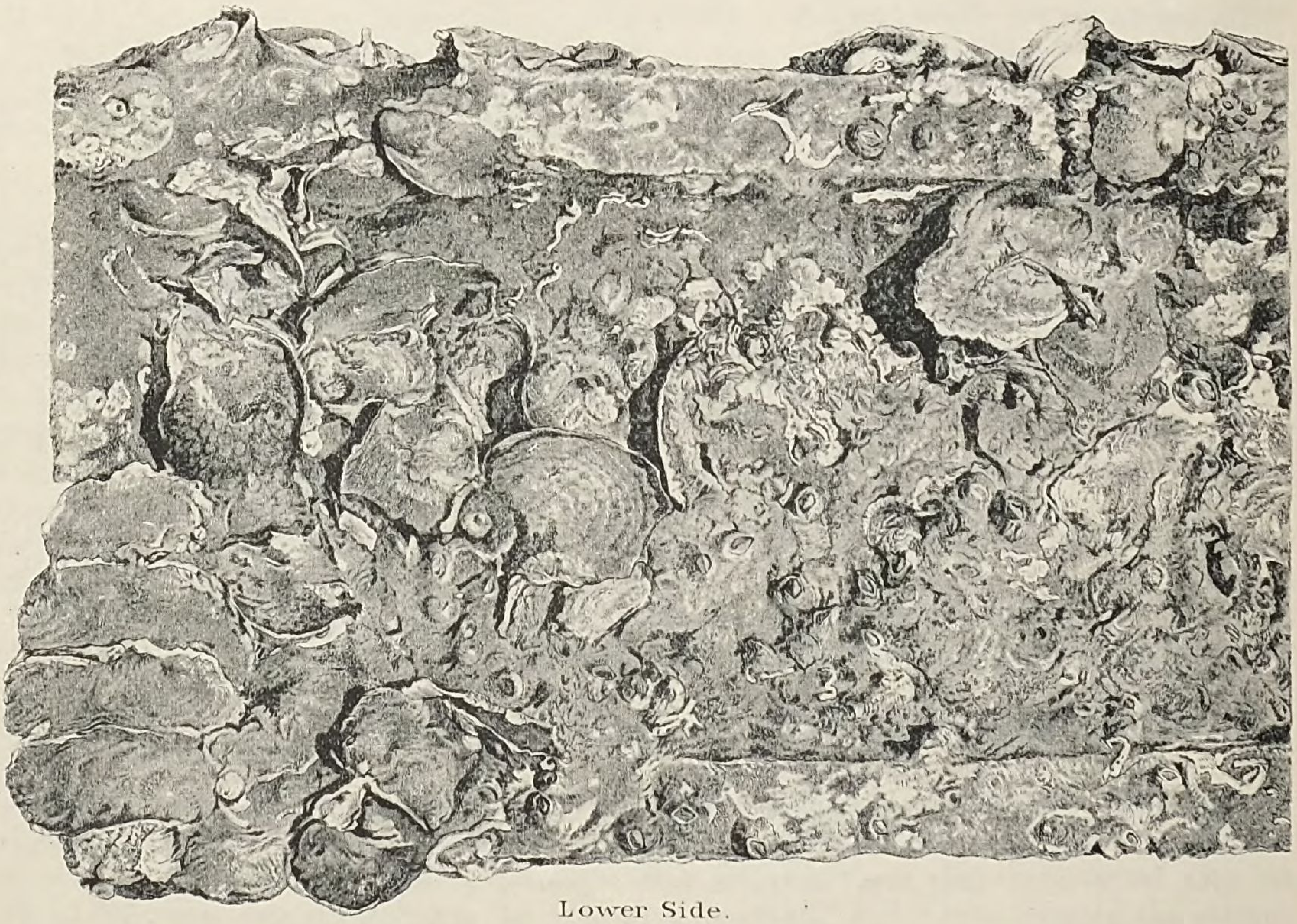
Stations were selected on these sections in such a manner as to obtain specimens of the water that passed over the beds, and the specimens were taken by means of the drop-water cylinders at every two fathoms of depth. As soon as possible after securing them they were tested with the hydrometer. The results are tabulated in the "record of densities," and curves showing the various changes accompany this report. All densities are reduced to a standard temperature of 60° Fahr., and 1,000 represents the density of distilled water.

## SPECIMEN TILE No. 6

Placed in position July 9th Removed October 10th
Scale 2/3 Natural Size.



Upper Side.



Lower Side.

A.Hoen & Co.Lithocaustic.Baltimore.

In studying these curves, it must be remembered that only their variations are of particular importance. The absolute density is not so much so, except for comparison with that of other localities; but the variations are important if by them we can account for the failure either of the propagation or attachment of the young oysters. The curves will show certain irregularities, due to either the variations in depth, or to the tides having changed from flood to ebb, or the reverse, on one side of the Sound at a time differing from that on the other.

As will be seen, however, the greatest variations in each month are in Tangier Sound, on the eastern side, where the influence of the rivers is felt to greatest extent. In Pocomoke Sound the greatest variations appear to be on the western side, and I assign as a reason for this that the influence of Guilford and Mesongo Creeks is of small importance compared with that of the Pocomoke River, the current from which sweeps along the northern and western parts of the Sound. The curves show that the variation is very slight, except on the September sections.

The second series of curves, those showing the monthly change of mean densities, indicate that the maximum change on each section was about the 1st of September; that the variations in Pocomoke Sound were much greater than in Tangier Sound; and that the maximum changes were at the head of each Sound, and the variations diminished towards the entrances.

The third series of curves shows the same when all the observations in each Sound are assembled, but with this difference—while the density in Tangier Sound was greater on October 1st than at any other time, in Pocomoke Sound the influence of the river was still felt; and notwithstanding the diminished temperature the density on the 1st of October was less than on the 1st of August.

The fourth series of curves shows the difference in density between the upper and lower sections in Tangier and Pocomoke Sounds in each month, and indicates that the density of the water is considerably greater over the lower beds than on the upper.

The maximum density found during the summer was on section 3, in October, and was 1.0166. The minimum density was found in section 5, in September, and was 1.0005.

By referring to the curves showing monthly changes of *mean* densities, it will be seen that in only one case, that of section 5, does the density become less than 1.0100, and that even on this section it is evident that this was not the normal condition of the water. There were heavy freshets in the Pocomoke River during the latter part of August and during September, which accounts for the slight density as shown by the curves. Mr. Barroll was informed by the inhabitants of the vicinity of the mouth of Pocomoke River that these freshets had killed large numbers of oysters, both on the natural and planted beds. An inspection of the other curves shows that the variation of density on successive tides was not much greater on this section than on the others, and as the oysters elsewhere in the Sounds did not appear to suffer from the effects of these variations, I am of the opinion that the fluctuation was not sufficient to affect the mature animal, but that in this case the water continued fresh, or practically so, for too long a period, thus killing the oysters by endosmose.

From the observations of density, then, it may be assumed that the density of the water, in these localities at least, cannot fall below 1.01 for any protracted period without destroying the oysters. Whether the changes in density affect the spatting can only be ascertained by continuing the observations for a number of seasons, or by direct experiment with the spat artificially raised.

## INCIDENTAL INFORMATION.

During the summer I have examined, under the microscope, 374 oysters, of which 212 were females and 162 males, or the percentage of females was 0.56. The oysters were not all examined at the same time, nor were they all from the same bed, but the percentage in each of the lots examined, twelve in number, does not vary greatly from the percentage given above. I am of the opinion, therefore, that about 60 per cent. of the oysters in a community are females. A larger number of observations is, however, desirable.

In making these examinations I have never seen both ova and spermatozoa in the same animal, though I have made many careful observations in order to detect the presence of either. I have also carefully examined the gills and mantles of a large number, and have never found an embryo oyster within the shell; and as these observations were made during the spawning season, I do not think it possible that the spat, if they are at any time contained within the gills or mantle, could have escaped my notice.

The observations as to the sex of the oyster were continued late in the season, and though the ova and spermatozoa in a number of oysters were in apparently good condition as late as the 1st of October, yet those products of generation appeared in best condition in the largest number of animals during July, and a considerable disintegration of the eggs was noticed by the end of that month. As far as I could ascertain, the condition of both ova and spermatozoa depended upon the depth of water, though the rule was not invariable. The generative products of the deep-water oysters reached a state most favorable for reproduction several weeks after the same had occurred in the shoal water; and, in general terms, neither ova nor spermatozoa in most of the oysters, in either deep or shoal water, after the middle of August, was in a state favorable for fertilization. Large numbers of oysters in all depths passed through the spawning season without expelling the contents of the generative organs. I found this the case especially on the beds on the western side of Tangier Sound, above Kedge's Strait, where, on the 8th and 9th of October, we found many oysters fattening with the generative matter unexpelled. I was informed that this was not unusual, and that it injured the oyster for marketable purposes. As late as the 8th I found oysters with the generative matter in good condition, and on the 7th of October I succeeded in securing from oysters taken from Kedge's Strait a sufficient amount of ova and spermatozoa to make experiments in artificial impregnation, and was successful in producing one embryo oyster. Probably had I used greater care a larger number would have resulted.

During the season of 1878 we observed large numbers of *astyris* in the shells of the mature oysters and attached to those of the young. In many cases they were found in the holes which had been bored in the shells of the latter. As we could not find any known enemy of the oyster in sufficient numbers to account for the evident damage done, and as so many circumstances pointed to *astyris* as the cause, I concluded that the boring must be done by that animal, and alluded to it in my previous report. The specimens preserved were described by Mr. W. H. Dall, and the description appended to that report. During the past summer we have found a much larger number of the rough welks (*urosalpinx cinereus*) than during the previous season, and though they were not found in as large numbers as the *astyris*, yet their presence inclined me to question the conclusions arrived at during the season of 1878. I accordingly collected a large number of *astyris* and placed them in an aquarium jar with a number of young oysters, changing the water constantly and inspecting the animals frequently. The observations were continued for over a week, and at the end of that time both oysters and *astyris* were alive, but there was no evidence of any boring, nor did any inspection show an inclination in that direction upon the part of the *astyris;* on the contrary, they soon left the shells and went to the bottom of the jar. I then collected a number of *urosalpinx cinereus* and subjected them to the same test. At the end of four days one oyster had been bored and one welk was found at work on the shell of another. The rough welk is known to do great injury to the oyster in Long Island Sound, and the destruction of the young, alluded to in my previous report as due to the drills, may be effected by this animal. That large numbers are destroyed by the welks cannot be doubted; but as it is possible that the *astyris* may also assist in this destruction, a more extended investigation of this question than I was enabled to make is desirable.

An analysis of several specimens of the water of the Sound and bay, by Prof. C. E. Monroe, of the Naval Academy, is appended to this report for use in comparing the localities investigated with others whose investigation may be subsequently attempted. The specimens have been selected from those taken on different stages of the tide and from different sections.

The only noticeable change on the beds this season was that the amount of red sponge appeared to be much less than in 1878. In other respects they are, to outward appearances, in a similar state, though the dredgers report them as much broken up and with an increased amount of *débris.*

### INFORMATION OBTAINED FROM "RECORD OF STATISTICS."

The member of the party on duty at Crisfield inspected, during the season, 496 vessels directly engaged in the oyster fishery, and the results of these inspections have been recorded in the record of statistics, which record, to a great extent, explains itself.

Owing to the large number of vessels dredging, it was frequently impossible to visit and inspect all that entered during the day. When such was the case, those inspected were selected from different classes and from different dredging grounds that a fair idea might be obtained of the number of oysters removed each day from each bed.

The method of examination was as follows:

The total number of bushels in the load given by the master of the vessel was recorded, with the number of hours of labor necessary to obtain that quantity, and other matters of statistical interest. Several samples of one-quarter or one-half bushel each were then selected from different parts of the load and the number of oysters of each class in each sample counted and recorded. The number of samples examined depended upon the number of bushels in the load and upon the character of the oysters, a large number being taken when the oysters appeared dissimilar, and when the quantity was great. At least three samples were usually examined. In most cases the average number of each class per sample was nearly the same as that given by each examination, and, consequently, it is assumed that a close estimate of the number of each class in the entire load was obtained by multiplying the number of each class in a bushel, as shown by the samples, by the total number of bushels in the load. From the record of these inspections I have been able to determine with practical accuracy the number of oysters of the several classes removed from the various beds by each description of dredging vessel.

After September 1, when the dredging began, we counted each day all the vessels in sight from the "Palinurus," specifying the size and the ground upon which they were working, and the masters of the dredging vessels were also requested to note the number of dredgers working in their vicinity, which they in many cases very obligingly did. As even with these data, the number of working days given on each bed is very small, and because no bed is dredged continuously during the season, but at intervals, I have divided the sections in a similar manner to that described in my previous report.

The first section includes the beds north of Piney Island Bar and the Muscle Hole; the second section, those from the Muscle Hole and Piney Island Bar to the Great Rock; the third section, the remaining beds in Tangier Sound; and the fourth section, all the Pocomoke beds. By this arrangement duplication of the vessels counted is prevented and the average number of vessels working each day is more nearly a correct estimate.

The vessels dredging on these several sections, as counted by ourselves and by their masters, have been assembled; the number of oysters assigned to each class of vessel working in the section has then been multiplied by the number of vessels of each class, and the total number of oysters taken off the beds in each section thus obtained. The number of oysters taken by any vessel in a day varies greatly, owing to the weather principally, but in assigning the quantity on each day, the number brought in by vessels of the same class, as shown by "record of statistics," has been used, as a more correct estimate is thus assured than would be given by using the average for the whole season. The following table has been compiled from the calculations, and shows the number of oysters taken from each section in a specified number of days; supposing the observations to have extended over a sufficient period, the number of oysters has been divided by the number of days, and the average number removed in each day thus obtained.

*Table showing estimated number of oysters removed in* 1879.

SECTION 1.—UPPER TANGIER SOUND.

| | Number of sail. | First class. | Second class. | Third class. | Fourth class. | First and second classes per sail. |
|---|---|---|---|---|---|---|
| Total number of oysters removed in 12 days | By 521 sail | 2, 322, 200 | 1, 934, 200 | 1, 382, 500 | 371, 000 | 8, 100 |
| Average per day | | 192, 683 | 161, 183 | 115, 200 | 30, 916 | |
| Total first and second classes per day | | 353, 866 | | | | |

*Table showing estimated number of oysters removed in* 1879—Continued.

SECTION 2.—MIDDLE TANGIER SOUND.

| | Number of sail. | First class. | Second class. | Third class. | Fourth class. | First and second classes per sail. |
|---|---|---|---|---|---|---|
| Total number of oysters removed in 17 days | By 634 sail | 2, 463, 800 | 1, 623, 860 | 1, 132, 060 | 384, 220 | 6, 400 |
| Average per day | | 144, 929 | 95, 521 | 66, 591 | 22, 600 | |
| Total first and second classes per day | | 240, 450 | | | | |
| SECTION 3.—LOWER TANGIER SOUND. | | | | | | |
| Total number of oysters removed in 34 days | By 951 sail | 2, 329, 600 | 1, 413, 610 | 1, 407, 230 | 558, 900 | 3, 900 |
| Average per day | | 68, 223 | 41, 576 | 41, 389 | 16, 438 | |
| Total first and second classes per day | | 109, 799 | | | | |
| SECTION 4.—POCOMOKE SOUND. | | | | | | |
| Total number of oysters removed in 9 days | By 169 sail | 256, 809 | 121, 103 | 88, 800 | 20, 108 | 2, 200 |
| Average per day | | 28, 534 | 13, 567 | 9, 866 | 2, 234 | |
| Total first and second classes per day | | 42, 101 | | | | |
| Total number of oysters first and second classes removed in one day | | | | | 746, 226 | |

It will be noticed that the number of dredging vessels increases on each succeeding section in Tangier Sound, but that the number taken by each sail, and the yield per day, decrease. Also, that the number of sail in Pocomoke Sound is much smaller than in any other section, and that the yield per day is also much smaller. The character of the bottom and the depth of the water materially influence the yield of the beds, those in shoal water with soft bottoms allowing more frequent hauls of the dredges than those in deep water or on hard bottoms. But as the dredges used in deep water and on hard bottoms are usually much heavier, this inequality is overcome to some extent. Again, the large vessels take a greater proportion of the oysters than the small ones, and those large vessels usually work on the deep-water beds. Considering the different sizes of the vessels and the superiority of the crews of the larger ones, and the heavier dredges used by them, I am of the opinion that the disparity between the yields of the Upper and Lower Tangier Beds is greater than it should be. The beds of the Middle Section are, with the exception of Piney Island Bar, similar to those of the upper section; yet, with a larger number of vessels working, the yield of that section is less than the upper. These facts, I think, show that the beds in Lower Tangier Sound are less productive than those in the upper.

The dredging in Pocomoke Sound was principally on the upper beds, and none was done as far as we could ascertain on either the Brig or Parker's Beds. As the middle and upper beds in this Sound are very similar in character of bottom and depth of water to the middle and upper beds in Tangier Sound, it would be inferred that the yield per day in Pocomoke would be about the same. On the contrary, as shown by the table, it is absurdly small; and, considering its size, it is not astonishing that the beds have been to a great extent abandoned.

Taking the number of oysters removed each day, and considering, for the reasons given in my previous report, the working season to be of 120 days, I have compiled the following table, in which is given the number of oysters removed from each section and from the Sounds in one day and in the season. I have also given the same estimated in 1878 for comparison.

*Table showing the number of oysters removed.*

| Section. | In one day. | | In one season. | | Number of young growth, 1879. | |
|---|---|---|---|---|---|---|
| | 1878. | 1879. | 1878. | 1879. | Per day. | In the season. |
| No. 1 | 567, 450 | 353, 876 | 68, 094, 000 | 42, 465, 120 | 146, 100 | 17, 532, 000 |
| No. 2 | 378, 450 | 240, 450 | 45, 414, 000 | 28, 854, 000 | 89, 200 | 10, 704, 000 |
| No. 3 | 459, 000 | 109, 799 | 55, 080, 000 | 13, 175, 880 | 57, 800 | 6, 936, 000 |
| No. 4 | 133, 650 | 42, 101 | 16, 038, 000 | 5, 052, 120 | 12, 100 | 1, 452, 000 |
| All sections | 1, 538, 550 | 746, 226 | 184, 626, 000 | 89, 547, 120 | 325, 200 | 36, 624, 000 |
| Bushels | 7, 692 | 3, 232 | 923, 230 | 447, 735 | | |

Two hundred oysters are allowed to a bushel.

The estimated number of young removed from all sections in one day, in 1878, was about 1,240,000, or 148,800,000 in the course of the season.

It will be seen by the table that about one hundred million more oysters were removed in 1878 than would be in 1879, and that about the same excess exists with regard to the young. Of the two estimates, that of 1879 is much more accurate, being based upon a larger number of observations, more carefully and systematically made than was possible in 1878, but the disparity between the two is so great that the estimate of 1878 would appear valueless, could not some cause be assigned for a decrease in the number of oysters taken from the beds. This decrease, as may be easily seen, must be due to one or both of the following causes:

1st. The fertility of the beds remaining the same, the dredgers may not be as numerous.

2d. The number of dredgers remaining the same, the beds may be exhausted; or, becoming so, there would be a smaller number of oysters produced; or,

3d. The number of dredgers may have decreased and the fertility of the beds may be greatly impaired.

There are no statistics of the oyster fishery in the localities under consideration except those collected by myself, and I am consequently obliged to put a greater dependence upon them than they intrinsically merit. They are necessarily somewhat rude, but, in the absence of other information, they can be used as giving some indication of the probable progress of the fishery in the two seasons under consideration.

By examining my previous report it will be seen that in thirteen days we counted 1,595 vessels working on the various beds in both Sounds. From our records of the past season I find that the number observed by all persons was, in thirty-seven days, 2,275, or in 1878 the average number working on each day was 122, while in 1879 it was 61, or one-half as many. Therefore, the small yield of the beds during the autumn months of 1879, and the small estimate of the yield for the year, may be accounted for by the smaller number of vessels at work, and as in round numbers the number of oysters estimated as taken in 1879 was about one-half that in 1878, I think that the previous estimate may be accepted as practically correct.

My last advices from Crisfield inform me that there is but very little dredging going on in the Sounds, most of the vessels working in the bay and in the Potomac River. The principal cause assigned for this is the presence of young growth on the beds, by which is meant immature oysters under two years of age. The presence of this class in large numbers prevents the oysters from fattening rapidly. Another reason given is that the beds are much broken up, and that the returns are very poor for the usual amount of labor.

## CONCLUSIONS.

My additional experience in the investigation and the information collected during the past season has proved that a few of the conclusions at which I arrived in 1878, and which are contained in my report of the operations of that season, are erroneous. Some of them have been already alluded to, and the allusions to the remaining ones here find their most appropriate place.

I find my supposition that there is a general attachment of spat on all the beds in any season, to be, to a certain extent, incorrect. The spatting may be general, and a majority of the oysters may spawn each year, but the attachment of the young is a very different thing, and as the most precarious period in the life of the oyster is that just anterior to its attachment, a series of causes detrimental to the life of the embryo, while it is in its free swimming state, may readily occur, and thus prevent such attachment. My investigation of the past season has proved conclusively that the class of oysters termed "young growth" in my previous report were not of the brood of 1878 but of 1877 or 1876. The character of the young found in both seasons, the determination of the time of earliest attachment, and the growth and appearance of the oysters on the tiles, have led me to this conclusion. As the young do not attach before the middle of August, they could hardly reach such a size and shape by October as would prevent their recognition as of the same season's growth. From the inspection of the oysters taken during the last season, many being found with the generative matter unexpelled, I am of the opinion that a combination of natural causes may prevent the expulsion of both the male and female cells, and there would consequently be no impregnation during that season. As I mentioned in the report of 1878, many persons of experience are of that opinion, and I now concur with them in thinking that not only the attachment of young may not be general nor occur each year, but that the emission of the products of generation may also be frequently confined to partial areas, and that by a combination of circumstances there can be a total failure of impregnation on all beds of any locality.

I also find by additional experience, that the young oyster is not fit for marketable purposes until at least a year and a half or two years old, and consequently the total number of young removed, as estimated in my previous report, would be a total sacrifice, and, as will be seen by the table showing the number of oysters removed, this sacrifice probably amounted in 1878 to 148,800,000 oysters.

By reference to the tables showing the success or failure of the several spatting seasons, it will be seen that there is little or no regularity of either success or failure, but as we have only been able to investigate the spatting of three seasons, it may be found by subsequent observations that two similar seasons of success, moderate success, or failure, will follow each other; but so far this has not been the case and in the period of three years we have, comparatively to the other seasons, one at least of successful attachment. I can see no reason for supposing that there is any regular recurrence of the spatting seasons, and am inclined to believe that the success or failure is due to two causes: variations of temperature and variations of density; but I had no means of ascertaining the changes either of temperature or density in the years preceding those in which I have been engaged upon this investigation, and in both seasons I arrived in the Sounds too late for the temperatures or determinations of density obtained by the party to be, with reference to the spatting, of practical value.

Oysters will and do live in very dissimilar temperatures and in waters of very different densities, as is shown by their existence in the waters of North America from Nova Scotia to the Gulf, and on both Atlantic and Pacific coasts. That the mature oyster is a hardy animal, readily adapting itself to new conditions and environment, is shown by the ease with which it is transplanted from the warm waters of the Chesapeake to the colder ones of New England; from the dense and salt waters of the ocean and bay to the brackish waters of the creeks and rivers or vice versa, and from soft bottoms to hard or the reverse; but, naturally, this hardiness is not a quality of the immature oysters or the swimming embryos.

The influence of increased or diminished temperature upon the formation of the ova and spermatozoa must be very serious, and, judging by analogy, it would seem probable that the formation would be more rapid during a warm spring than during a cold one. Whether the formation has been late or early when once formed, a sudden change of density or of temperature may so affect the oyster or the generative matter that the latter would not be expelled. Only upon this hypothesis can be explained the retention of the products of generation noticed in so many oysters, and which is said to be so common, for none of the other conditions are subject to violent changes, such being peculiar to the density and temperature alone.

Professor Brooks states that he found both ova and spermatozoa ripe and fit for fertilization about the middle of May, and as the oysters were taken from shoal water, probably one fathom deep, the shoal-water oysters were probably spawning throughout June. Both Professor Brooks and myself found the ripeness of the oysters to depend upon the depth of water from which they were taken, and this is without doubt caused by the difference of temperature. Professor Brooks also states that there was a great deal of cold, rainy weather during June, and two hail storms. The rainy weather would affect the density of the water by increasing the volumes of the various creeks and rivers, and the changes of density would probably affect the production and emission of the generative matter. It is an interesting coincidence at least, that the oysters found to be fattening with the products of generation unexpelled were either from beds in comparatively shoal water, or from the shoal parts of deep-water beds, and that those oysters should have been ripe and spawning during the month of June. Again, it may be that the lowness of the temperature prevented the deep-water oysters from ripening as soon as usual, and the mildness of the succeeding autumn may have prevented the destruction of the ova and spermatozoa, thus rendering possible the fertilization achieved by me in October, as the oysters from which I procured the ova and spermatozoa were taken from deep water.

Probably the influence of changes of environment, especially of density and temperature of the water, is most severely felt by the embryo when in their free swimming state, and, in connection with the want of success of the spatting season in the Sounds, it is noticed that the temperature curves show a maximum change about the time when it is supposed that the young would attach in largest numbers, or when they were swimming about in the water. It is also worthy of notice that Professor Brooks, about this time, met with the minimum amount of success in his efforts to artificially raise the embryo.

In consideration of the foregoing, I am of the opinion that the success or failure of any spatting season is dependent upon the equability of the temperature; that the higher the temperature during the spring months the earlier will be the advent of the spawning season, and that an increased temperature will also hasten the development of the spat, and of the young oysters after they have become attached. I also infer that sudden and extensive changes of density will likewise affect the advent, duration, and success of the spawning, though to a less extent. Subsequent to the attachment of the animal, changes of the conditions surrounding it are not of so much importance, though naturally such changes will more severely affect the delicate organism of the young oyster than that of the older and more hardened adult.

During the first six months of its existence the oyster is exposed to the greatest danger from the numerous enemies which surround it. The thin, delicate shells, from one-sixteenth of an inch to one inch in diameter, are readily bored by the drills or torn off by the crabs, and the immense number of both leaves no room to doubt their destructive effects. As an instance, the inspection of the spat collectors in the Big Annemessex River shows that during the early months of their existence about 50 per cent. of the young oysters were destroyed. Naturally, as the animal progresses, it becomes more hardy and better able to resist the attacks of enemies and changes of environment, and thus we find on the unworked beds, where the oysters are practically in a natural state, that the decrease in passing from young growth to mature oysters is about 30 per cent., or about one-third of a given number perish in passing from the first to the fourth year of their existence.

Here our information ceases, but enough has been gathered to indicate the ratio which nature has assigned as necessary between the young and the mature oysters. For every 1,000 of the latter there should be 1,500 of the former, if the number of brood oysters necessary to maintain the fecundity of the beds is to be kept up, and though this ratio is based upon *data* which are not quite sufficient, yet, as I have said, it is all that has been afforded as yet, and may be accepted within certain limits. Certainly, whatever it should be, the number of the rising generation of the animals should never be less than that of the older, or there should always be as many young as mature on any bed, and a greatly increased ratio of young to mature oysters would show either one of two things—either the mortality in passing from youth to maturity was much greater than shown by the dredging results in the bay, or that a very large number of mature oysters had been removed by other than natural causes.

In considering these several beds the question of food and other necessary supplies has not been considered, as it is evident that where an oyster bed is formed and exists naturally, all the conditions for its successful life are probably present, and any failure of an important supply would be followed by a speedy extinction of all the oysters on the bed. Such determinations of the quality and quantity of the food, character of bottom and water, and other matters, are only of interest and desirable for the purpose of comparing one locality with another. Such was not the purpose of this investigation, and consequently the determination of those points has been but incidental to the work.

Probably the fecundity of a bed is increased, to a certain extent, by working upon it. The dredges or other implements used open the bed and spread it, thus giving more room for development, and allowing a greater amount of food to reach the animals, and as the mortality is great in all thickly-populated tracts and in any closely-united community, it is evident that no removal of brood oysters could be effected without destroying the fecundity of the bed, did not this very removal influence the mortality among the young so as to allow a larger number to come to maturity. But the removal of brood oysters may become so great that the most violent exertions of nature to supply others are unequal to the demand, and it must be evident that as soon as the number of brood oysters is thus diminished, the fecundity of the bed is impaired.

This impairment constantly increases, influencing, as it does, both old and young. As the number of the latter decrease, so will the number of the former, and as that number is again and again diminished, the number of young produced by them must constantly diminish. Thus the cause for the destruction of the fecundity of the bed and the gradual extinction of the animals upon it can be readily understood and as easily comprehended as the fact that the fecundity or productive power of a bed depends upon the number of mature spawn-bearing oysters upon it. It is not meant by this that none but the mature oysters are capable of reproduction, as such is not the case, oysters of even six or nine months' growth having been observed by me with ripe ova and spermatozoa in them, but the main dependence must be placed upon the adults in the community, as the spawn of the young growth is not considerable when compared with that of the other class.

Without a knowledge of the number of oysters on a bed it is impossible to say what number should be removed, and as an attainment of the knowledge of the number on the bed is almost impossible, all that can be done is to keep the ratios between the young and the mature as nearly the same as on the natural beds; this should be the aim and result of all laws having the protection of the beds in view.

Referring to that portion of this report relating to the fecundity of the beds in the Sounds, it is seen that in some cases the ratio of young to mature oysters is greater, and in other cases less, than it should be, and that in a few cases the ratio seems to be within the prescribed limits. As has been shown, the decreased ratios must be the result of a want of reproduction, while the increase may be due to the removal of the mature oysters.

If we take the total number of the oysters examined in the Sounds we will have a ratio expressing the general fecundity of the beds, and this ratio between 70,866 mature oysters and 36,824 young ones is 0.5. Assembling all the oysters counted on the beds in the bay we would have as a ratio 1.5.

Practically, none of the mature oysters had been removed from the beds in the bay, while large numbers had been taken from those in the Sounds. The estimates for each show, approximately, how many have been taken, and if by examination we find that the number of young oysters taken off the beds in the Sounds greatly exceeds the number of mature removed, it may be assumed that the restoration of both classes to the beds would be immediately shown by a change in the ratio of young growth to mature oysters. By the estimate of 1878 we find that 184,600,000 mature and 148,800,000 young were removed, but as the number of young removed would be less and less during the season on account of the mortality among them, and as we have found that mortality to be about 50 per cent., I will consider that the removal of the young during the season of 1878 and 1879 probably did not exceed 74,400,000. Therefore the total number removed was 259,000,000, of which 71 per cent. were mature, spawn-bearing oysters, and as 65 per cent. of the oysters at present on the beds are mature, the addition of the 260,000,000 removed would raise this percentage to 68, which would make the ratio of young to old even smaller. Consequently the small percentage of young is not due to the removal of that class during the previous season.

The two beds of which we have the most exact and complete statistical records in this season are the Woman's Marsh and the Great Rock, and, by means of the record of statistics, I estimate that the following number of oysters have been removed from them:

*Table showing number of oysters removed from Great Rock and Woman's Marsh.*

| Name of bed. | Removed in a year. | | Total both classes. | Percentage of mature. |
|---|---|---|---|---|
| | Mature. | Young. | | |
| Great Rock | 10, 176, 000 | 5, 640, 000 | 15, 816, 000 | 64 |
| Woman's Marsh | 1, 740, 000 | 768, 000 | 2, 508, 000 | 69 |

From Table II, dredging results in the Sounds, I find the percentage of mature oysters to the total number on the two beds mentioned is on the Great Rock 24, and on the Woman's Marsh 36. Hence, if there had been no fishing, we would have on the Great Rock 44 per cent. of the oysters mature and full grown, and on the Woman's Marsh 52 per cent. mature. We find by making a similar calculation for Piney Island Bar that the percentage of mature oysters removed is 70, and that by the dredging results 20 per cent. of those on the bed were mature; hence, 45 per cent. would represent the percentage on Piney Island Bar had there been no fishing. The ratios on these beds would then, were the oysters removed still present, be 1.2 on the Great Rock, 0.9 on the Woman's Marsh, and 1.2 on Piney Island Bar.

It will be seen by the above that there has been a severe fishing of many of the beds in the Sounds during the last four or five years—that is, exhaustive of mature brood oysters—and that consequently the large ratios of young to mature oysters is not the result of a large attachment of young, but rather of the removal of the older oysters, and hence the change from a large ratio to a very small one, or *vice versa*, may be regarded as a safe indication of the deterioration of the bed; for, as explained in the previous part of this report, the ratio will remain abnormally large until the young growth reach maturity, when it will become abnormally small, and will so remain for a few years, when it will again become very large, and this process will continue for some time until the beds are practically unfit for dredging, as is the case in Pocomoke Sound. Thus not even the ratios are sure indications of the increase or decrease in the number of oysters, but they must be considered together with other facts before we can arrive at just conclusions.

By reference to the closing paragraphs of that part of the report relating to the fecundity of the beds, it will be noticed that the amount of *débris* increases on the southern Tangier beds, and that on most of the beds of the Sounds it is much greater than it was in the bay. An increase of the percentage of *débris*, as already pointed out, is an indication of the deterioration of the bed, and is due to the destructive effects of the dredging, which not only removes many oysters, but so disturbs many others that their destruction is an almost assured fact. To a certain extent this is a necessary incident of the fishery, and cannot be helped; but overworking the beds increases this evil as well as others, as is evident by the percentage on many of the Pocomoke beds.

Referring to the table showing the number of oysters removed in 1878, and comparing it with the table of number of oysters to the square yard, the following may be noticed:

1st. In the upper part of Tangier Sound the numbers to the square yard are very large, which is probably due to the shoalness of the water and the soft bottom, which allowed a larger number of oysters to be taken. In addition, the mature oysters are smaller than on the southern beds, as shown in Table I, dredging results; thus a greater number would be taken in the dredge, and the number to the square yard increased.

2d. Though the numbers to the square yard are very large, yet there is a serious decrease from that established in 1878.

By reference to the "Table showing number of oysters removed," I find that the largest number of oysters were removed from this section in both seasons, and, supposing the number of dredging vessels to have been constant, instead of diminishing one-half, the number of oysters removed in 1879 would be greater by 14,000,000 than the number removed in 1878, or, in other words, the fishing is proportionally increasing. As this fishing is confined principally to the mature oysters, it can be readily understood why the number of these oysters to the square yard should be much decreased.

In the second section we find the numbers to be nearly the same as those outside; that there is a gain in the rivers where there is the minimum amount of dredging, and also on two beds which were worked very little in 1878–'79, on account of the young growth which had attached to them. The proportional increase of dredging, as shown by the numbers removed in each season, and supposing the number of dredging vessels to have been the same, would be, on this section, 11,000,000; these were taken principally from the western beds and Piney Island Bar, and on those beds there is a diminished number to the square yard.

Again, we find by reference to the tables, that on the southern beds in Tangier Sound the number to the square yard is much smaller than on the beds in the bay. This is due probably to two causes—the condition of the bed, or the depth of the water, hardness of bottom and size of the oysters, and to the removal of too large a number of mature oysters during previous years. As I have pointed out, where the number on a worked bed falls much below that on an unworked one, it must, other things being equal, be accepted as an indication of a decrease in the productivity of the bed. That much is assured; but on this section there appears to be an increase in the number of oysters to the square yard over the number found in 1878, and that increase must be accounted for in some way.

The table showing the number of oysters removed proves the number taken from this section to be a constantly decreasing one, for in 1878 there were taken by twice as many vessels four times as many oysters as were removed in 1879. This may be due to two causes, and probably is due, to some extent, to both. The productivity of the beds may be impaired, or the fishery may be less earnest and exhaustive than in the past. We can only account for the increased number to the square yard by assuming the latter to be the case, the beds having probably enforced a resting period by the material failure of the oysters.

The numbers to the square yard and yield in Pocomoke Sound need no comment. Not only are the numbers below the standard and decreasing, but the yield is also decreasing, as it naturally would under such circumstances.

Naturally, as soon as any bed ceases to give an adequate return for the labor expended upon it, the dredging vessels will seek other and more profitable fields for exertion, and the desertion of any bed may be accepted as an indication of its decreased productive power. As has been mentioned under the head of statistical information, dredging vessels have, to a great extent, left the Sounds for the waters of the bay and Potomac River.

Considering the abnormal ratios between the mature and young oysters, the increased percentage of *débris* on the beds, the smallness of the number to the square yard, and the decrease of those numbers on most of the beds, together with the large number of oysters, young and old, annually removed, I am of the opinion that though the fecundity of the beds in Tangier Sound is not yet destroyed, it is very much impaired, and that not only are the beds rapidly and surely deteriorating from the excessive fishery, but that their total failure, like unto that in Pocomoke Sound, is but a question of time.

So far as it is possible to make any more exact prediction than the above, I am of the opinion that, the fishery still continuing, this failure will occur first on the beds at the entrances of the Sound or those in sections 1 and 3, and of the two the failure of the lower beds is most likely to first occur, and of all the beds the Woman's Marsh will be the first to give out.

As stated at the beginning of this report, the beds may be protected either indirectly by enlarging the areas for the dredgers or insuring by artificial means the maturity of a larger number of spat; or directly, by limiting and restricting the fishery. I alluded in my previous report to the manner in which this latter form of protection was afforded abroad, and suggested a manner for affording it at home. The necessity for the adoption of some such measures seems so urgent that I earnestly hope they will shortly be undertaken.

The extension of the dredging ground can be easily attained by depositing the shells from the shell heaps about the packing houses on the bottoms contiguous to the natural beds; but such deposit should always be made in the direction of the ebb and flow of the tide, in order that the drifting spat may be carried over the newly-exposed cultch. The bottom is of minor importance so long as it is of sufficient consistency to prevent the oysters from sinking into the mud. A sticky clay bottom is preferable, though the beds may be extended over sand shoals.

In searching for new beds they will probably be found about the mouths of estuaries and rivers, and where there are sudden changes of bottom. In the Chesapeake, depths of from two to four fathoms will be most likely to reward a search, and where there are large beds in the creeks and rivers it is likely that there has been a natural expansion through their mouths, and beds will probably be found off of them. The search must be carefully conducted, or the beds, which appear to be long, narrow ridges, will be missed. The dredge should be dragged across the tide, as the beds usually extend in the direction of the current. A sudden change of depth of two or three feet, and from soft to hard bottom when on an oyster ground, is an unfailing sign of the presence of a patch or bed.

Considering the success which has attended the investigation of Professor Brooks, and the new light which it has thrown upon the embryo life of the oyster, I think that perhaps the most efficacious means of maintaining the productive power of the beds would be in bringing, if such be possible, the artificial impregnation of the eggs and subsequent care of the young to such a state of perfection as would be of practical utility. Professor Brooks is, of course, the best person to devise the method of successfully continuing his experiment, and I hope that he may be able to do so and that he will meet with complete success. As pertinent to his work, which is mainly conducted by means of aquaria, I would suggest that the study of the effect of changes of temperature, so far as they affect the embryo, can be best and most easily done while engaged upon the attempt to artificially raise them; or, in order to arrive at certain conclusions with regard to the effect of changes of density or of temperature, the investigation, if conducted on the natural beds, must be extended over many seasons in order to insure, by a coincidence of temperatures or densities and results, the elimination of other affecting conditions. The study of the temperature seems so important that any suggestion with regard to it is of value and should claim attention.

I would also recommend that some person inspect and count, at intervals, the oysters on the spat collector in the Big Annemessex River. It is securely moored and buoyed with a spar buoy, and probably will remain in place.

With regard to the direct protection of the beds in the Sounds, I can only renew my previous recommendations.

The deterioration of any bed will be evident by an abnormal ratio of young growth to mature oysters; by a small and decreasing number to the square yard; by large and increasing percentage of broken shells and other *débris*, and by the appearance of the oysters, as has been described.

When all these indications are present, if the dredging is not totally prohibited it should at least be so limited as to insure the number of young growth remaining at least one third greater than the number of mature, and great changes from this ratio are to be avoided and guarded against.

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## *APPENDIX A.*

*Areas of oyster beds.*

| | *Square yards.* |
|---|---|
| Fishing Bay Beds (solid) | 3,600,000 |
| Fishing Bay Beds (scattered) | 25,605,000 |
| Were Point (solid) | 1,845,000 |
| Shark's Fin (solid) | 1,867,000 |
| Nanticoke (solid) | 3,465,000 |
| Clump Point (solid) | 382,000 |
| Horsey's Bar (solid) | 202,000 |
| Tyler's (solid) | 675,000 |
| Drumming Shoal (solid) | 2,430,000 |
| Cow and Calf (solid) | 292,000 |
| Bed east of Bloodsworth Island (solid) | 4,027,000 |
| Cedar (solid) | 337,000 |
| Turtle Egg Island (solid) | 1,620,000 |
| Mud (solid) | 1,845 000 |

*Areas of oyster beds*—Continued.

| | *Square yards.* |
|---|---|
| Chain Shoal (solid) | 1,192,000 |
| Muscle Hole (solid) | 3,060,000 |
| Piney Island Bar (solid) | 6,975,000 |
| Manokin River bed (solid) | 6,142,000 |
| Big Annemessex (solid) | 2,835,000 |
| Harris' (solid) | 3,420,000 |
| Terrapin Sands (solid) | 1,417,000 |
| Paul's (solid) | 765,000 |
| Woman's Marsh (solid) | 6,975,000 |
| Bed off Jane's Island Light (solid) | 1,800,000 |
| Great Rock (solid) | 8,505,000 |
| Little Thoroughfare (solid) | 720,000 |
| Great Thoroughfare (solid) | 1,597,000 |
| Oak Hammock (solid) | 630,000 |
| California (solid) | 3,915,000 |
| Johnson's (solid) | 1,395,000 |
| Brig (solid) | 517,000 |
| Parker's (solid) | 495,000 |
| Beach Island (solid) | 225,000 |
| Hern Island (solid) | 2,092,000 |
| Bird (solid) | 3,285,000 |
| Guilford Creek (solid) | 1,642,000 |
| Messongo (solid) | 180,000 |
| Muddy Marsh (solid) | 1,912,000 |
| Buoy Spit (solid) | 427,000 |
| Small bed south of Shell Bed (solid) | 225,000 |
| Shell (solid) | 877,000 |
| Trevise (solid) | 697,000 |
| Drum Bay Point (solid) | 337,000 |
| Dog-Fish (solid) | 720,000 |
| Flat (solid) | 742,000 |
| Small bed north of Trevise (solid) | 135,000 |
| Slate Stone (solid) | 967,000 |
| Potter's (solid) | 900,000 |
| New Plantation (solid) | 180,000 |
| Buoy (solid) | 967,000 |
| Old Rocks (solid) | 1,057,000 |

TANGIER AND POCOMOKE—SUMMARY.

| | |
|---|---|
| Total area in both Sounds occupied by oysters | 425,012,000 |
| Total area in both Sounds occupied by solid oyster beds | 92,520,000 |
| Ordinarily scattered | 313,345,000 |
| Thinly scattered | 19,147,000 |

| | *Nautical square miles.* |
|---|---|
| Tangier Sound (solid) | 17.101 |
| Tangier Sound (scattered) | 44.926 |
| Pocomoke Sound (solid) | 4.519 |
| Pocomoke Sound (scattered) | 29.599 |
| Fishing Bay (solid) | 0.875 |
| Fishing Bay (scattered) | 6.225 |
| Total area both Sounds covered by oysters, or scattered oysters, in *square miles* (nautical) | 103.255 |

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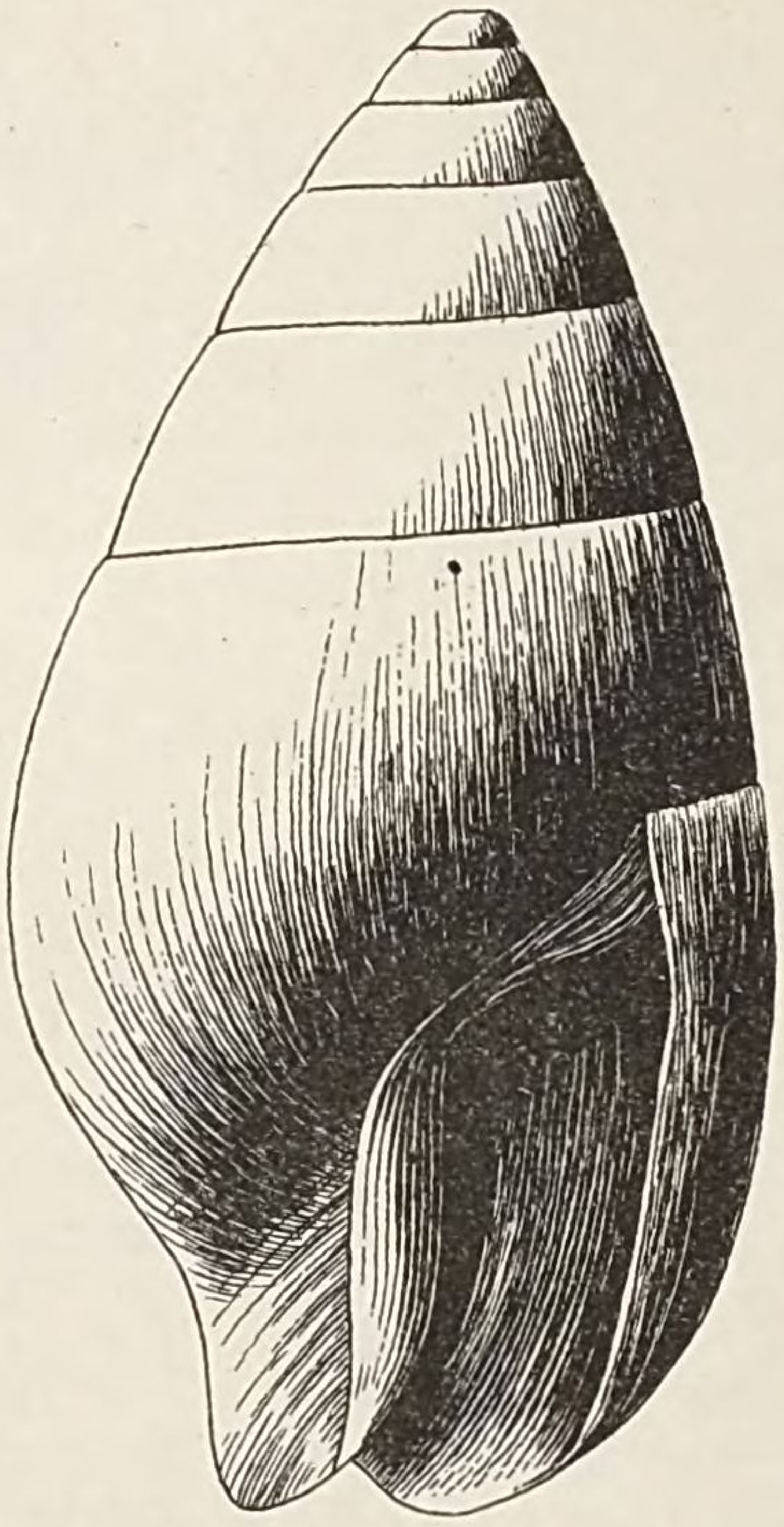
NOTE.—Those areas designated as "solid" are those where the number to the square yard was above 0.1, or more than one oyster to ten square yards.



ASTYRIS: variety WINSLOVII

CHESAPEAKE BAY, NEAR CRISFIELD, MD.

Reported to be injurious to young oysters

SCALE: $\frac{20}{1}$

## *APPENDIX B.*

### DESCRIPTION OF THE "DRILL" REFERRED TO IN THE REPORT OF THE OPERATIONS DURING THE SEASON OF 1878.

By W. H. Dall, Asst. C. & G. Survey.

Only a few specimens were preserved, and hence it is impossible to speak positively in regard to its distinctness from the allied forms *Astyris spizantha* (Rav.) and *A. lunata* Dall (Ex. Say).

It differs from the former, so far as the specimens go, in color, pattern, and solidity, having also more whorls and a more slender form.

It differs in form very much from southern specimens of *A. lunata*, but more specimens of each are needed to determine the limits of variation in these small shells. They belong to a group known to be extremely variable.

It may for the present be denominated by the varietal name *Astyris* var. *Winslovii* in commemoration of its discoverer.

Though known to be carnivorous, no species of the genus *Astyris* has been recorded until now as an injurious animal.

## *APPENDIX C.*

*Table showing number and class of dredging vessels seen from the Palinurus during the season of* 1878.

| Date of observation. | Number of sail. | Class. | Ground on which at work. | Number of bushels. | Number of young. |
|---|---|---|---|---|---|
| 1878. | | | | | |
| Sept. 18 | 57 | 2 | Pocomoke Sound | 946 | ............ |
| 19 | 43 | 2 | ......do | 714 | ............ |
| 20 | 51 | 1 | Southern part Tangier Sound | 2, 142 | 432, 684 |
| 20 | 61 | 2 | Pocomoke Sound | 1, 013 | ............ |
| 23 | 123 | 1 | Southern part Tangier Sound | 5, 166 | 1, 043, 532 |
| 25 | 85 | 1 | ......do | 3, 570 | 721, 140 |
| 26 | 104 | 1 | ......do | 4, 368 | 882, 336 |
| 29 | 65 | 1 | Middle part Tangier Sound | 2, 730 | 551, 460 |
| 30 | 20 | 2 | Manokin River | 332 | ............ |
| Oct. 1 | 37 | 1 | On the "Great Rock" | 1, 554 | 313, 908 |
| 3 | 26 | 1 | On Harris' Bed | 1, 092 | 220, 584 |
| 3 | 20 | 1 | On Terrapin Sands | 840 | 169, 680 |
| 3 | 16 | 2 | On Muscle Hole | 266 | 53, 732 |
| 3 | 14 | 1 | On Piney Island Bar | 588 | 118, 776 |
| 3 | 25 | 2 | Manokin River | 415 | ............ |
| 3 | 63 | 2 | On and above Chain Shoal | 1, 046 | ............ |
| 4 | 115 | 2 | Above Diel's Island | 1, 909 | ............ |
| 4 | 17 | 2 | On Muscle Hole Bed | 282 | 56, 964 |
| 4 | 6 | 1 | On Terrapin Sands | 252 | 50, 904 |
| 4 | 30 | 1 | Southern part Tangier Sound | 1, 260 | 254, 520 |
| 4 | 79 | 1 | Harris' Bed and Manokin River | 3, 318 | 670, 236 |
| 4 | 112 | 2 | North of Little Island | 1, 859 | ............ |
| 7 | 210 | 3 | Upper Tangier Sound | 6, 090 | ............ |
| 14 | 210 | 3 | ......do | 6, 090 | ............ |

The classification of the dredging vessels is the result of, and dependent upon, actual observations. It was noticed that those vessels usually at work in a particular locality were generally of a certain rig and tonnage, and where there was a dissimilarity in that respect, we recorded, when in the locality, the proportion of large and small vessels and of different rigs. In compiling the table the dredging vessels have been separated into three classes.

The first class represents *large and small* vessels; the average "take" of this class was 42 bushels per vessel.

The second class represents *small* vessels; the average "take" of this class was 16.6 bushels per vessel.

In the third class, two-thirds of the vessels were *small* and one-third *large;* the average "take" of this class was 29 bushels to the vessel.

By actual count, we found the average number of young to a bushel to be 202.

## *APPENDIX D.*

With the assistance of Mr. H. J. Rice, the following interrogatories were prepared and used during the season. The information obtained from the oystermen, which has been incorporated in the previous pages, is the result of the answers to the questions.

### NAME AND LOCALITY OF OYSTERMAN.

1. Please state your name and your P. O. address.
2. In what place or places do you take oysters?
3. How long have you been engaged in the business?

### THE BEDS: THEIR LOCALITY, CONDITION, &C.

4. Please give the location and the names of the beds in your neighborhood with which you are acquainted.
5. What is about the size of each bed?
6. On what kind of bottom are these oyster-beds generally formed?
7. Is this bottom subject to change in any manner?
8. What are the causes of such change or changes?
9. Does mud or sediment ever accumulate upon the beds?
10. Is it injurious in any manner to the oysters?
11. From whence does it come?
12. Can such deposit be prevented?
13. State average depth of water where these beds are found.
14. State the greatest and least depths.
15. Are the largest and best beds found near by, or distant from, the channels?
16. Does a change of channel affect them in any manner?
17. Has there been any change in any of the channels in your vicinity?
18. Have such changes, if any, affected the beds; and, if so, how?
19. What is the direction and amount of current over these beds?
20. Do you know of any beds that are "running out;" if so, how and from what causes?
21. Where are these beds?
22. Do you know of beds which are improving in any manner; if so, in what does this improvement consist? What is the cause of this improvement?
23. What is the general direction of the gales which are prevalent here in winter?
24. What in summer?
25. Which of these gales increase, and which decrease, the depth of the water over the beds?
26. Do the gales in winter affect the ice-fields in any manner; and, if so, how?
27. Do they ever seriously affect the beds, or change the neighboring shores; if so, in what manner, and to what extent?
28. If the water should be blown off from any of the beds during such gales would it injure them?
29. How long can the beds remain uncovered without injury?
30. How long have you ever known any to remain uncovered?
31. Is this a common occurrence?
32. Is ice ever piled up on the beds during such times, and on what beds?
33. For how long?
34. Has this piling up of ice any injurious effect upon them; and if so, what effect?

35. What thickness of ice do you generally find over the beds?

36. Does an increased thickness of ice affect the beds either in deep or shallow water; and, if so, what is the effect?

37. Is it greater or less in deep than in shallow water?

38. Does long continued cold weather affect them?

39. Is the effect greater in shoal or deep water?

40. During such cold spells does the ice ever rest upon the beds; and, if so, what is the effect?

### THE OYSTER ON THE BEDS.

41. Are the oysters in your locality found mostly in large or small compact beds, or scattered over a great extent of surface and lying far apart?

42. How does their quality compare, as far as you know, with those of other localities?

43. Are they with you better flavored inside or outside of the Sounds and rivers?

44. Are they affected in any manner by long continued dry or wet weather?

45. What is the effect, if any, of long continued dry weather?

46. What is the effect of a large amount of fresh water pouring over the beds?

47. Do the oysters grow better in deep or shallow water?

48. Are they found in the channels, or where there is mud?

49. Have the oysters in your locality any particular enemies?

50. What are their enemies?

51. How destructive are these enemies to the oysters, and in what way?

52. Are there any means of destroying these enemies without incurring too great expense, or injuring the oysters, and what are such means?

53. Do you know the nature of the oyster's food, and what is such food?

54. Does it feed at any particular time, and what is such time?

55. What is the length of time it is occupied in feeding?

56. Will freezing kill the oysters of a bed?

57. If so, how long must they be frozen before they are destroyed?

58. Which of the beds in your locality produce the finest-flavored oysters?

59. How large do the oysters grow in your locality?

60. Do some of the beds produce larger oysters than others?

61. If so, which ones?

62. What causes this?

63. As far as you are aware, what is the greatest size which oysters will attain under natural conditions?

64. Are oysters attached to any objects, or to each other, or do they grow up separately and flat on the bottom?

65. At what time of the year do oysters spawn in your neighborhood?

66. Is there any difference in the sex of oysters, or are they hermaphrodites?

67. What are your reasons for thinking so?

68. If they are of different sexes, can you distinguish the male from the female before being taken from the shell, and how?

69. Is there any change in shape or color in either sex during the breeding season; if so, what is such change?

70. Is there any change at any other time?

71. At what age does the female commence to breed?

72. At what age does the male?

73. Is there any age after which oysters do not breed?

74. At what age do oysters produce the most young?

75. How do you know this?

76. Does the act of spawning seem to affect oysters injuriously in any manner; if so, how?

77. Do all the oysters of a bed spawn at or near the same time?

78. Have you ever seen young oysters floating or moving about in the water?

79. If so, were they in considerable numbers?

80. Is there any marked difference in the time of appearance of the young in different years?

81. Are the young especially liable to be destroyed?

82. If so, by what?

83. Can this destruction, if any, be prevented; and, if so, by what means?

84. What is the average growth of an oyster during the first year?

85. Have you ever known any disease to attack the oyster whereby great numbers were destroyed or rendered unfit for use?

86. If so, is such disease common, and at what times does it attack the oysters? What is the common local name of the disease?

87. What are the supposed causes of such disease?

88. Are about the same number of young found each year upon each bed?

89. Do some beds produce young some years and not others; and during these resting years do other beds produce young, and then rest in their turn?

90. Do all the beds rest periodically and at the same time?

91. Do currents or unusual conditions of the water appear to have any effect upon the time of spawning?

### THE WORKING AND CULTIVATION OF THE OYSTER.

92. In your neighborhood how are the oysters taken from the beds—with dredges or tongs?

93. Does it improve or injure a bed to work it over with tongs or dredge?

94. Which of these two implements should be used for the best interests of the beds?

95. Are any beds improved by the use of one and not of the other; if so, of which?

96. Does the depth of water make any difference?

97. What kind of boats do you use in oystering?

98. After the oysters have been taken from the bed are they immediately culled, or do you wait until the fishing is over; and are they culled on their beds?

99. Are the small oysters thrown back or not?

100. What is the size of the smallest which are kept?

101. For the best interests of the beds, what proportion of oysters should be taken off each year?

102. So far as you know, or can judge, what proportions are taken from the different beds in your locality?

103. Is there a limit to the thickness of the layer of living oysters upon a bed; if so, what is such limit?

104. About what is the average thickness?

105. Should a bed be allowed to rest for certain definite periods?

106. If so, how long?

107. Will oysters fatten best upon the same beds upon which they are produced?

108. If not, what is the character of the bottom upon which they will fatten best?

109. Are oysters planted to any great extent in your vicinity?

110. What kind of oysters are best to use as plants, or does it make any difference which are used?

111. At what time are they taken up to plant?

112. At what age?

113. How are they taken—with dredge or tongs—and which is preferred?

114. Are they injured at all by rough handling, either for market or for planting?

115. What kind of places are most suitable for planting beds?

116. Do oysters breed on planted beds?

117. If so, do the young oysters thrive as well as on the natural beds?

118. If not, why?

119. Are oysters taken from your locality to other places to plant?

120. If so, where?

121. About how small are the oysters in your neighborhood when they first spawn?

122. Is there any difference in this respect, or in the time of year when they spawn, between those on the natural and those on the planted beds?

123. Does a wet or dry season affect the time of spawning, or the coming to maturity of the spawn?

124. Is there any difference as to the amount of young growth found on the beds in different years?

125. What is the reason for this?

126. Have any means ever been tried in your locality to propagate the oyster by artificial means other than by planting; if so, what means?

127. Do you ever attempt to increase the amount of "cultch," or objects upon which the young can become attached, by placing old shells or other rough substances in the water upon the beds?

128. Is there any law for the protection of oysters in your locality; if so, please give reference to date of law?

129. If so, is it carried out?

130. Are there any means by which protection is afforded to the oyster, to allow them to increase upon the beds, other than such law, if this exist?

131. Do the oystermen try to uphold all laws and all methods for the protection and increase of the oysters?

132. What is your method of fishing for oysters—with tongs or dredge?

### OYSTER ECONOMY.

133. At what age are the oysters upon the beds in your locality best for market purposes?

134. What size are they at that age?

135. Do the oystermen try and select only such oysters from the beds, or do they take everything that will sell?

136. What is the size of the smallest marketable oysters?

137. How old are they?

138. Are oysters divided into classes according to their market value?

139. If so, what are these classes, and how recognized?

140. Do oysters from particular beds command better prices than those from other beds near by?

141. If so, what are the names of the preferred beds?

142. What is considered a profitable day's work with a dredge?

143. Can you catch that number now?

144. What kind of a boat, and how many men are employed with a dredge?

145. What is the size of the dredge?

146. In what depth of water can it be used most profitably?

147. Do all the men on board a dredging-boat share in what is taken, or are they paid regular wages?

148. If paid regular wages, how much per day?

149. What is considered a profitable day's work with the tongs?

150. Can you catch that number now?

151. In what depth of water can the tongs be used most profitably?

152. Do oystermen fish exclusively for any one grade of oysters, such as those which will do for barreling, or for canning, or do they catch promiscuously all and everything?

153. What kind of a boat is used in tonging, and how many men in each boat?

154. Which is most profitable, to tong or dredge exclusively?

155. If dredging is injurious to the beds, is it more or less so in deep than in shallow water?

156. Why?

157. Would it not be most profitable to catch one grade of oysters exclusively, and that the first grade?

158. Is a very fat oyster more profitable for barreling, or for canning, than one not very fat?

159. Are oysters sold by the load or by measure?

160. What is the price paid at present time?

161. What is the highest price you have ever received for oysters?

162. What is the lowest?

163. When was this?

164. What do you consider a profitable price for oysters?

165. Can an oysterman catch as many to-day, in the same number of hours fishing, as he could when you first began to fish?

166. What is the reason for the difference in the catch?

167. How many could one catch at that time?

168. What was the price then?

169. Does the price vary on account of flavor or fatness?

170. If so, which commands the better price?

171. To what market do your oysters go?

172. Do the oystermen dispose of their catch to the dealers or to traders?

173. How long can oysters be carried in an oyster vessel without injury?

174. In what shape can they be carried best?

175. Must any particular care be taken when transporting them?

176. About how many persons are engaged in oystering in your neighborhood?

177. How many vessels do they employ?

178. From your experience, what do you consider would be the best means of improving the beds and the quality of the oysters in your vicinity, for the best interests of the oystermen and of the general public?

### FOR THE OYSTER PACKERS.

179. In what shape do you put up oysters?

180. What is your process?

181. About how many do you put up in a season?

182. From what part of the country do you procure your oysters?

183. What do you pay per measure or load?

184. How many oysters are there in a load?

185. Where are most of your oysters sent?

186. With barrel oysters is there any particular manner of packing them in a barrel?

187. Can you give any information from your books as to the number of bushels purchased and the number of gallons obtained from them each year?

## *APPENDIX E.*

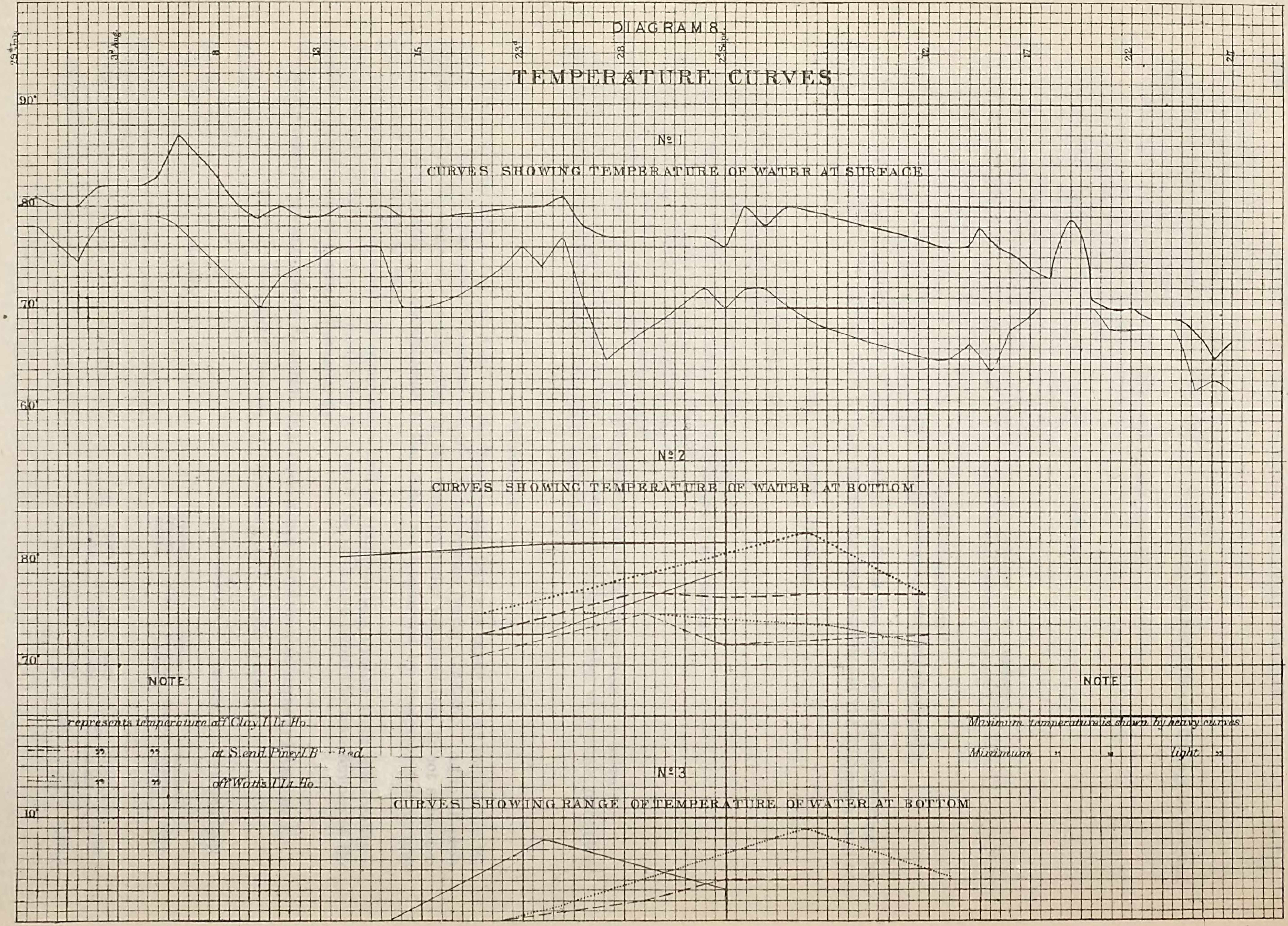
The following analysis of the water of the Sounds and Bay was made at my request by Mr. Charles E. Monroe, Professor of Chemistry at the United States Naval Academy. As in all probability the chemical character of the water in the locality under consideration is not subject to frequent or great changes the constituents of the water as determined by Professor Monroe may be accepted as the normal ones.

The analysis furnishes data for comparison, and in transplanting oysters from this locality it will be of advantage to the oyster culturist to consult the table and avoid the transference of the oysters to conditions of marked dissimilarity.

### ANALYSIS OF WATER FROM TANGIER AND POCOMOKE SOUNDS AND CHESAPEAKE BAY.

By C. E. MONROE, *Professor of Chemistry, U. S. Naval Academy.*

| Locality. | Total solids at 120°. | | Chlorine. | | Sulphuric acid. | |
|---|---|---|---|---|---|---|
| | Separate determination. | Mean. | Separate determination. | Mean. | Separate determination. | Mean. |
| Section 1, Station C— | | | | | | |
| High water | 18,000 | 18,000 | 9,370 | 9,390 | 1,532.6 | 1,525.3 |
| | 18,000 | | 9,400 | | 1,518.0 | |
| Low water | 17,340 | 17,339 | 9,080 | 9,090 | 1,507.8 | 1,482.4 |
| | 17,338 | | 9,100 | | 1,457.0 | |



## DIAGRAM 8.

## TEMPERATURE CURVES

Nº 1

CURVES SHOWING TEMPERATURE OF WATER AT SURFACE

Nº 2

CURVES SHOWING TEMPERATURE OF WATER AT BOTTOM

Nº 3

CURVES SHOWING RANGE OF TEMPERATURE OF WATER AT BOTTOM

NOTE

represents temperature off Clay I. Lt. Ho.
" " at S. end Piney I. B[illegible]Red.
" " off Watts I. Lt. Ho.

NOTE

Maximum temperature is shown by heavy curves
Minimum " " " light "

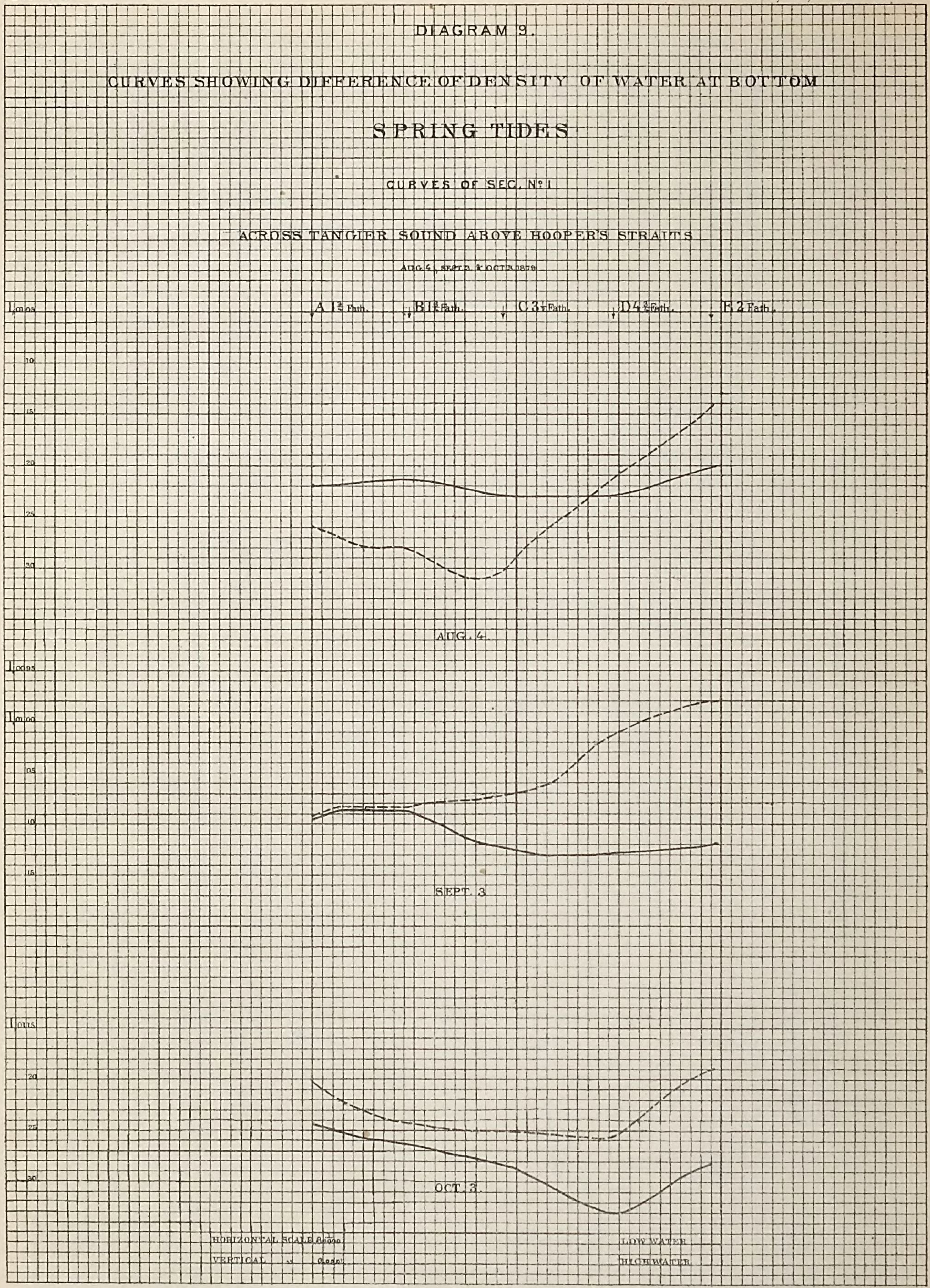


DIAGRAM 9.

CURVES SHOWING DIFFERENCE OF DENSITY OF WATER AT BOTTOM

SPRING TIDES

CURVES OF SEC. Nº 1

ACROSS TANGIER SOUND ABOVE HOOPER'S STRAITS

AUG. 4, SEPT. 3 & OCT. 3 1879

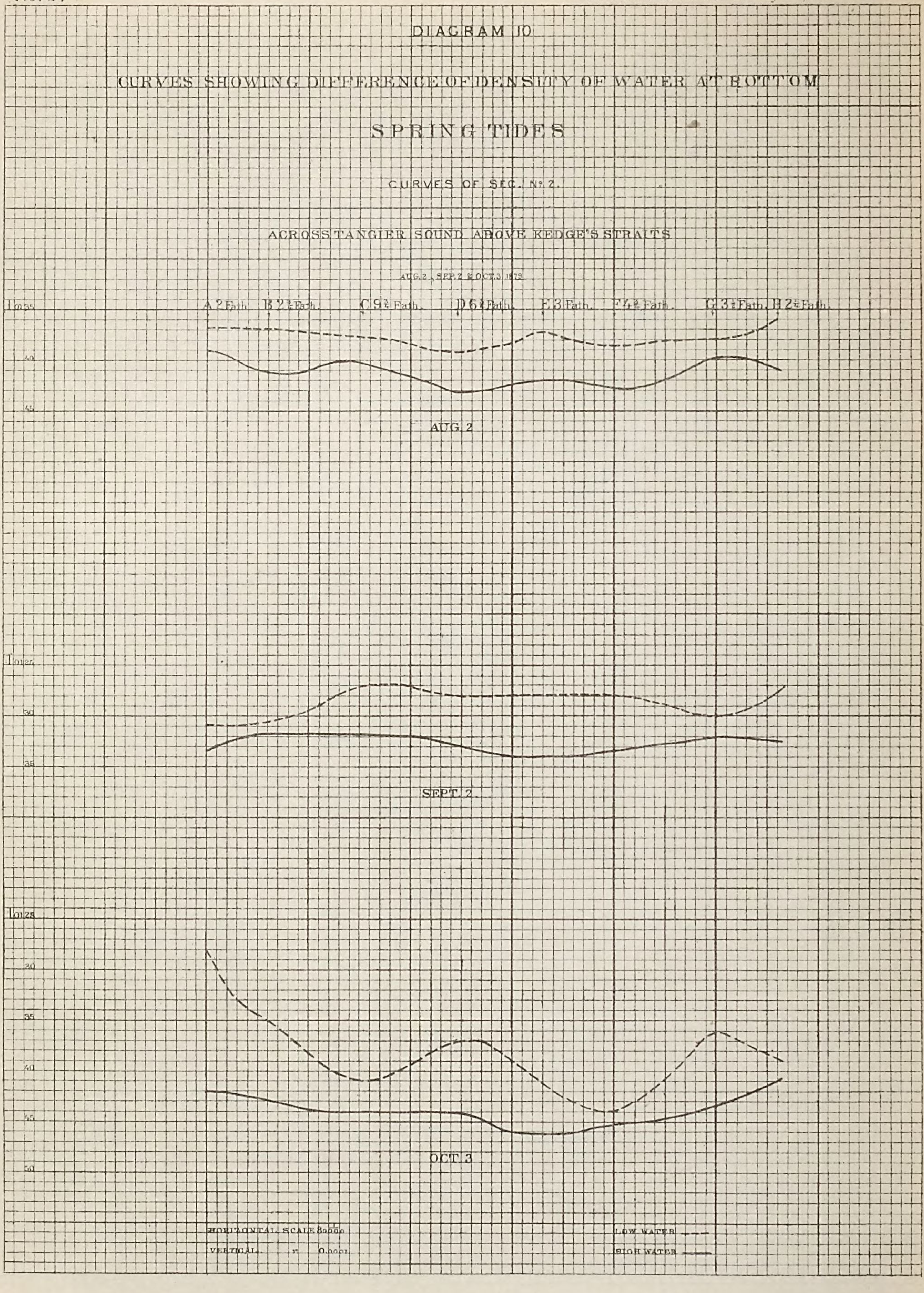


DIAGRAM 10

CURVES SHOWING DIFFERENCE OF DENSITY OF WATER AT BOTTOM

SPRING TIDES

CURVES OF SEC. No. 2.

ACROSS TANGIER SOUND ABOVE KEDGE'S STRAITS

AUG. 2, SEP. 2 & OCT. 3 1879.

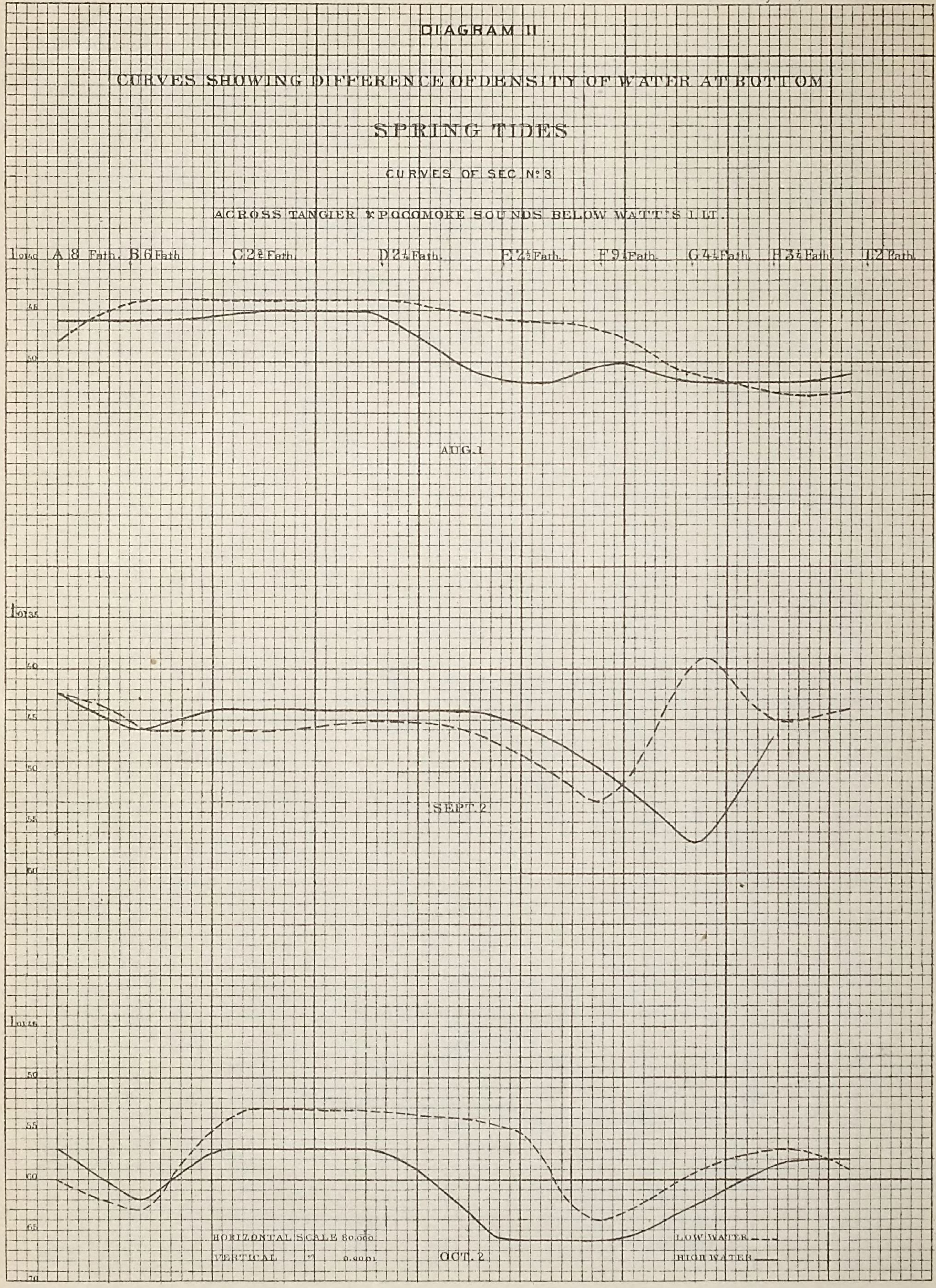


DIAGRAM II

CURVES SHOWING DIFFERENCE OF DENSITY OF WATER AT BOTTOM

SPRING TIDES

CURVES OF SEC. Nº 3

ACROSS TANGIER & POCOMOKE SOUNDS BELOW WATT'S I. LT.

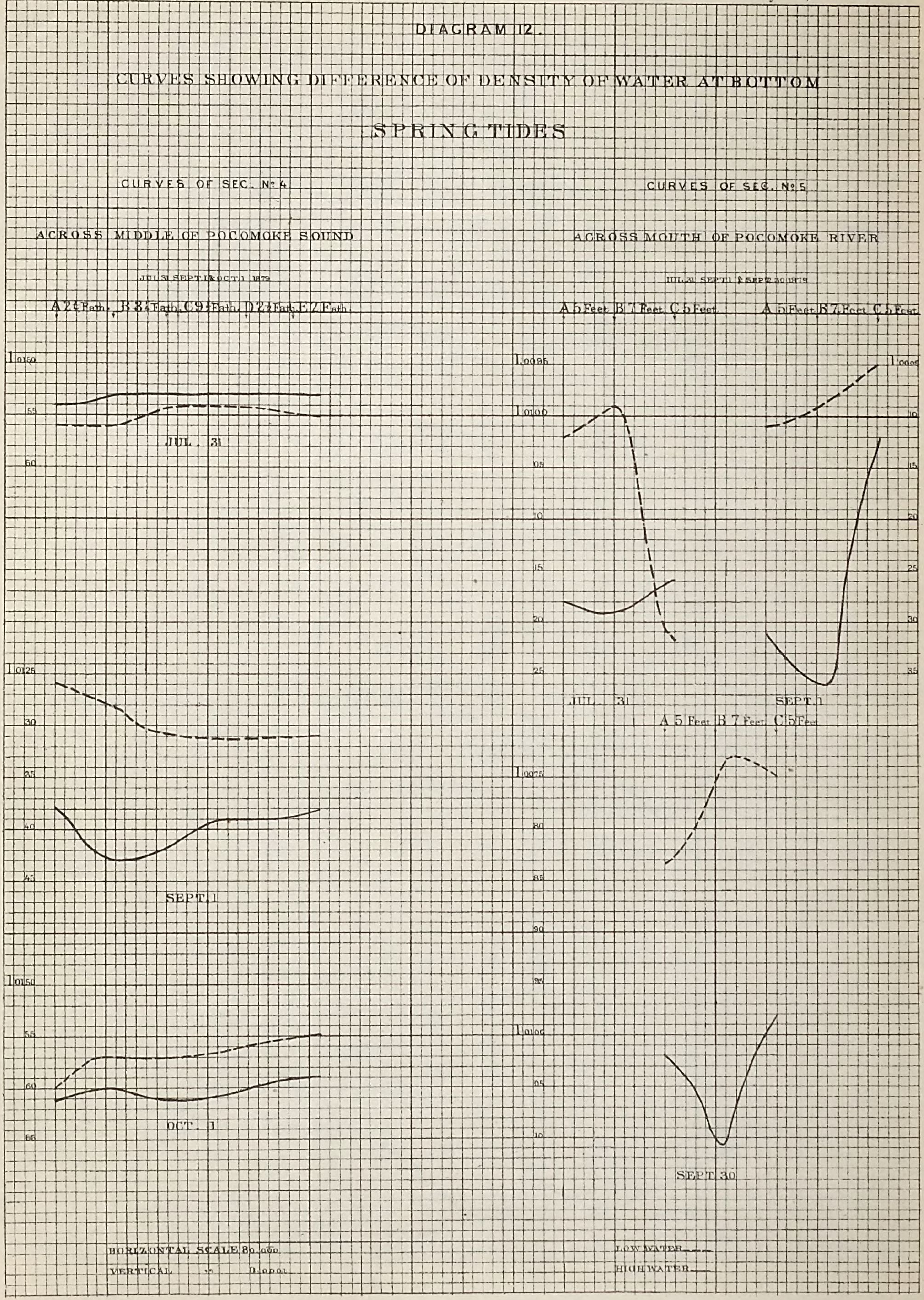


DIAGRAM 12.

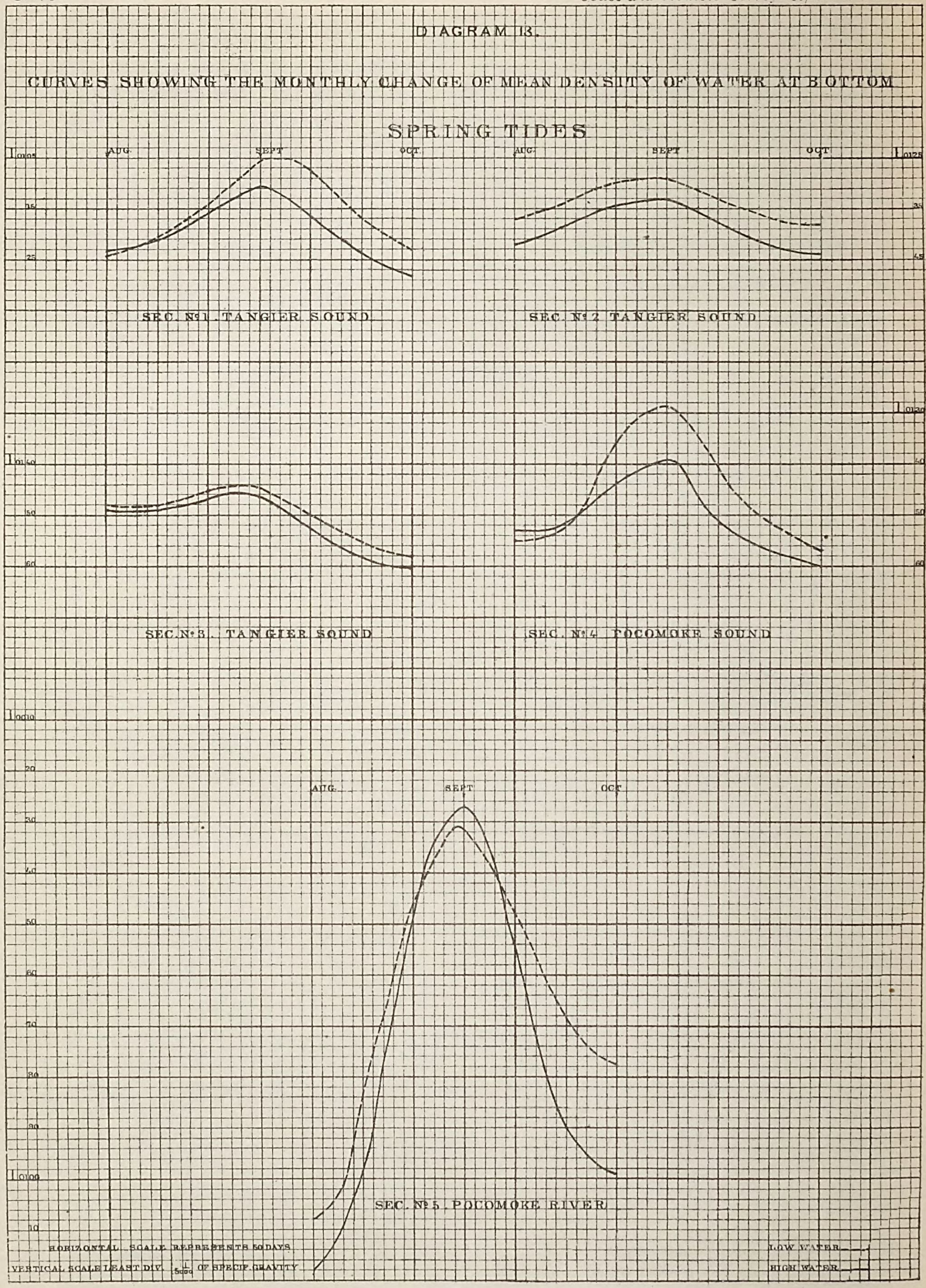
CURVES SHOWING DIFFERENCE OF DENSITY OF WATER AT BOTTOM

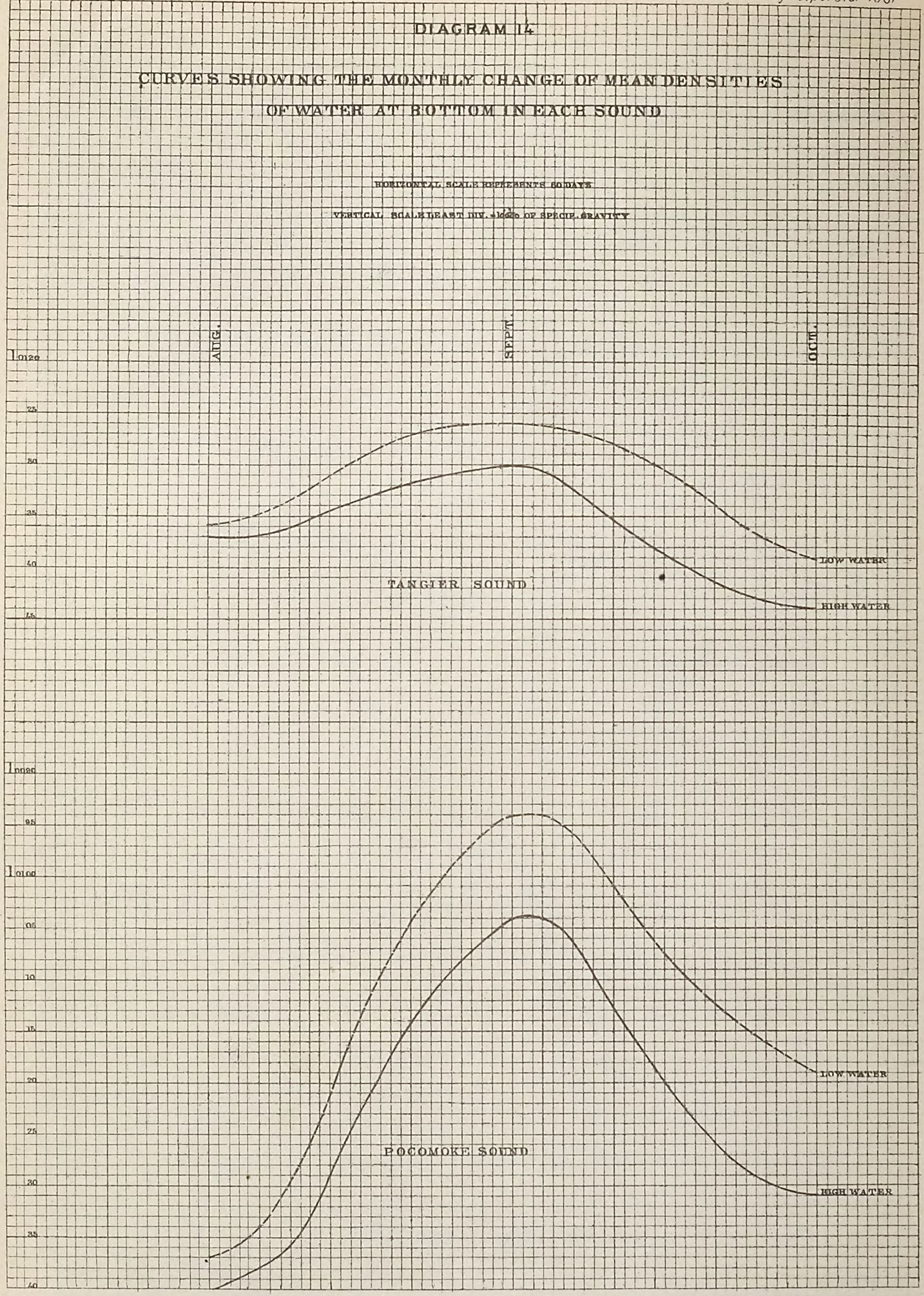
SPRING TIDES

# DIAGRAM 13.

## CURVES SHOWING THE MONTHLY CHANGE OF MEAN DENSITY OF WATER AT BOTTOM

## SPRING TIDES



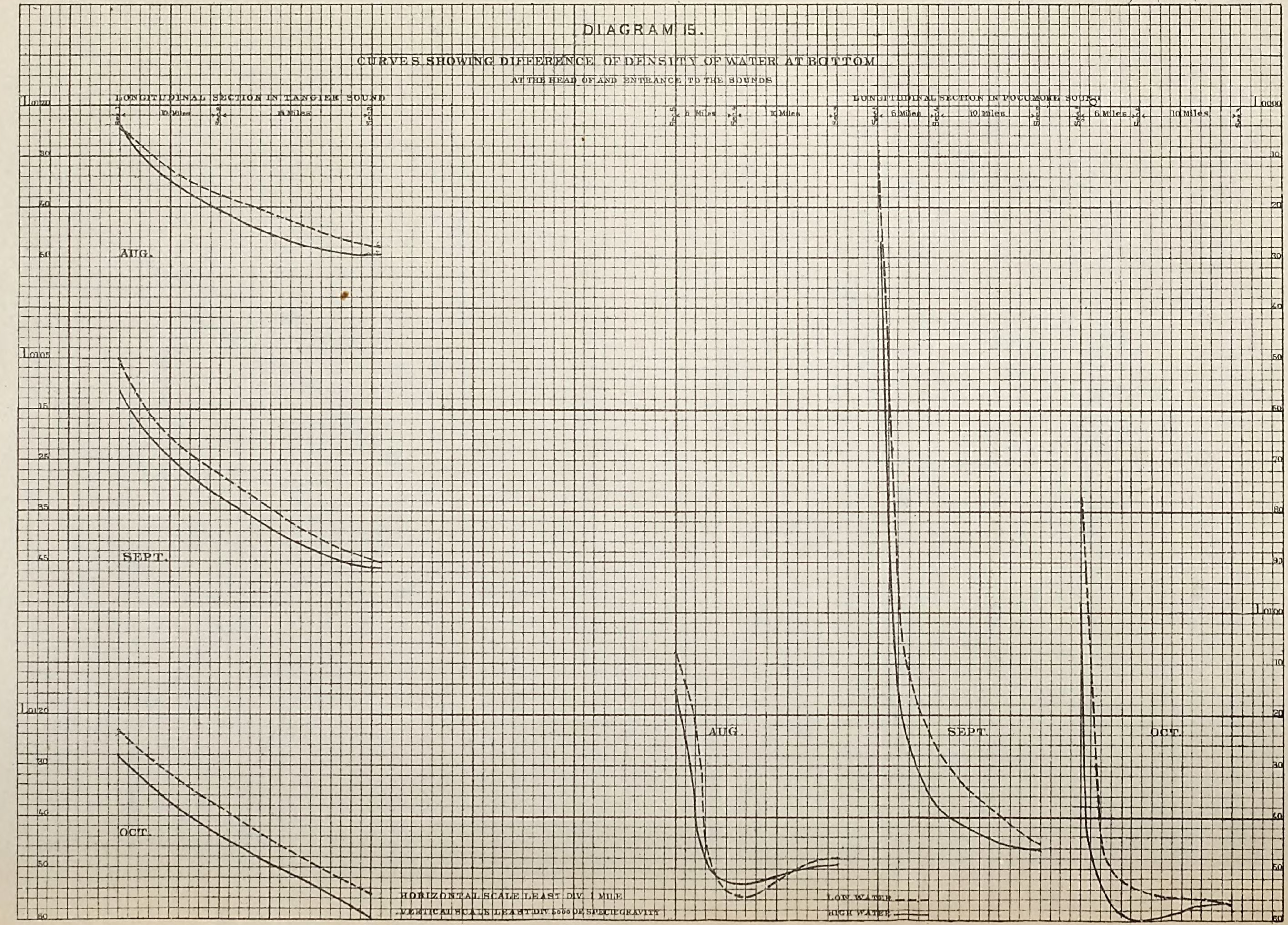


## DIAGRAM 14

CURVES SHOWING THE MONTHLY CHANGE OF MEAN DENSITIES OF WATER AT BOTTOM IN EACH SOUND

HORIZONTAL SCALE REPRESENTS 60 DAYS

VERTICAL SCALE LEAST DIV. = 1/10000 OF SPECIF. GRAVITY



## DIAGRAM 15.

### CURVES SHOWING DIFFERENCE OF DENSITY OF WATER AT BOTTOM

AT THE HEAD OF AND ENTRANCE TO THE SOUNDS

*Analysis of water from Tangier and Pocomoke Sounds and Chesapeake Bay*—Continued.

| Locality. | Total solids at 120°. | | Chlorine. | | Sulphuric acid. | |
|---|---|---|---|---|---|---|
| | Separate determination. | Mean. | Separate determination. | Mean. | Separate determination. | Mean. |
| Section 2, Station E— | | | | | | |
| High water | 20, 904<br>20, 800 | 20, 852 | 10, 820<br>10, 840 | 10, 830 | 1, 708. 4<br>1, 694. 8 | 1, 701. 6 |
| Low water | 19, 850<br>19, 830 | 19, 845 | 10, 460<br>10, 500 | 10, 480 | 1, 662. 8<br>1, 645. 6 | 1, 654. 1 |
| Section 3, Station B— | | | | | | |
| High water | 23, 118<br>23, 122 | 23, 120 | 11, 880<br>11, 920 | 11, 900 | 1, 948. 2<br>Lost. | 1, 948. 2 |
| Low water | 23, 568<br>23, 454 | 23, 511 | 12, 020<br>12, 100 | 12, 060 | 1, 995. 6<br>1, 994. 6 | 1, 995. 1 |
| Section 3, Station F— | | | | | | |
| High water, A | 23, 200<br>23, 324 | 23, 262 | 12, 120<br>12, 080 | 12, 100 | 1, 960. 0<br>Lost. | 1, 960. 0 |
| High water, B. | 23, 670<br>23, 678 | 23, 674 | 12, 160<br>12, 200 | 12, 180 | 2, 002. 0<br>2, 006. 0 | 2, 004. 0 |
| Section 4, Station C— | | | | | | |
| High water | 23, 200<br>23, 180 | 23, 190 | 12, 080<br>11, 960 | 12, 020 | 1, 952. 8<br>1, 955. 4 | 1, 954. 1 |
| Low water | 22, 210<br>22, 238 | 22, 224 | 11, 680<br>11, 720 | 11, 700 | 1, 923. 2<br>1, 822. 4 | 1, 872. |
| Chesapeake Bay— | | | | | | |
| Stations 18 and 19, bottom water | 18, 306<br>18, 410 | 18, 358 | 9, 800<br>9, 760 | 9, 780 | 1, 578. 0<br>1, 541. 6 | 1, 595. 8 |
| Atlantic Ocean— | | | | | | |
| Latitude 41.18 N., longitude 36.28 W | .......... | 38, 400 | .......... | 20, 839 | .......... | 3, 029. 8 |

NOTE BY PROFESSOR MONROE.—No determinations of organic matter were made, as it was found that the amount was so small that it could not be readily determined in the small sample furnished.

No determinations of Ca were made, the time given for the analytical work not permitting it. It will be seen from the analysis that the water consists of ocean water more or less diluted with fresh water, and that the proportion of fresh water is greater at low tide than at high, except in the case of station B, section 3.

Another feature to be noticed is that the proportion of sulphates in the water analyzed to that in the Atlantic water is greater than that of the chlorides; this point is important.

As both samples of water from section 3, station F, were taken at high water I have designated them as A and B.

# APPENDIX No. 12.

## ON THE LENGTH OF A NAUTICAL MILE.

BY J. E. HILGARD.

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The length of a nautical mile is defined as the one-sixtieth part of that of a degree of a great circle of the earth. If the earth were a perfect sphere of known dimensions, the lengths of a nautical mile, according to the above definition, would be a definite and invariable quantity.

Owing, however, to the earth's compression, and the consequent difference in the lengths of the radii of curvature at different points of its surface, much diversity has arisen, in usage and in books of reference, in assigning the length of a nautical mile.

Thus it is variously given as equal to—

The mean length of a minute of latitude on the meridian.

The length of a minute of the meridian corresponding to the radius of curvature of the particular latitude.

The length of a minute of longitude on the equator, the latter definition being probably due to the common use among mariners of Mercator's projection, in which the degrees of the successive parallels of latitude are equal to those on the equator.

In order to remove all uncertainty and to introduce uniformity this office adopted, several years ago, the value which results from considering the nautical mile as equal to *the one-sixtieth part of the length of a degree on the great circle of a sphere whose surface is equal to the surface of the earth.* This value, computed on Clarke's spheroid, is: One nautical mile=1853.248 meters=6080.27 feet, a value which corresponds to the adopted length of the Admiralty knot=6080 feet.

In the following tables are given the numerical results of the discussion relating to this subject:

*Figure of the earth from Clarke's combination of geodesic measures.*

Equatorial radius, $a=6378206^{m}$ [6.8046985]  Polar radius, $b=6356584^{m}$ [6.8032238]

and

$$\frac{b}{a}=\frac{293.98}{294.98} \qquad c=\frac{1}{294.98}$$

1. *Length of 1′ on the equator:*

$$\begin{array}{ll} \log a & 6.8046985 \\ \log 1' & 6.4637261 \\ \hline & 3.2684246 \end{array}$$

$$\text{Length of } 1'=\overset{m.}{1855.345}=\overset{feet.}{6087.15}$$

2. *Length of 1′ of latitude at the equator:*

Radius of curvature$=\frac{b^2}{a}$

$$\begin{array}{ll} \log b^2 & 3.6064476 \\ \log a & 6.8046985 \\ \hline \log \dfrac{b^2}{a} & 6.8017491 \\ \log 1' & 6.4637261 \\ \hline \log & 3.2654752 \end{array}$$

$$\text{Length of } 1' = \overset{m.}{1842.787} = \overset{feet.}{6045.950}$$

3. *Length of* 1′ *of latitude at the poles:*

Radius of curvature $=\dfrac{a^2}{b}$

$$\begin{array}{ll} \log a^2 & 3.6093970 \\ \log b & 6.8032238 \\ \hline \log \dfrac{a^2}{b} & 6.8061732 \\ \log 1' & 6.4637261 \\ \hline & 3.2698993 \end{array}$$

$$\text{Length of } 1' = \overset{m.}{1861.655} = \overset{feet.}{6107.85}$$

4. *Length of* 1′ *on the meridian in latitude* 45°:

Radius of curvature $= \frac{1}{2}(a+b) - \frac{7}{8}ac^2$

$$\begin{array}{ll} \log \frac{1}{2}(a+b) & 6.8039618 \\ \log 1' & 6.4637261 \\ \hline & 3.2676879 \end{array}$$

$$\begin{array}{ll} \log a & 6.8047 \\ \log c^2 & 5.0604 \\ \log 1' & 6.4637 \\ \hline & 8.3288 \end{array}$$

$ac^2 \times 1' = 0.0213$

$$\begin{array}{r} 1852.200 \\ -\frac{7}{8} \times 0.0213 = -0.019 \\ \hline \end{array}$$

$$\text{Length of } 1' = \overset{m.}{1852.181} = \overset{feet.}{6076.76}$$

5. *Length of a quadrant of the meridian:*

$$\text{Length of quadrant} = \tfrac{1}{4}\pi(a+b)\left\{1+\tfrac{1}{4}\left(\frac{a-b}{a+b}\right)^2+\frac{1}{64}\left(\frac{a-b}{a+b}\right)^4+\ldots.\right\}$$

$$\tfrac{1}{4}\left(\frac{a-b}{a+b}\right)^2=\tfrac{1}{4}\left(\frac{1}{588.96}\right)^2=0.0000007,$$

$$\begin{array}{ll} \log \frac{1}{4}(a+b) & 6.5029318 \\ \log \pi & 0.4971499 \\ \log 1.0000007 & 0.0000003 \\ \hline & 7.0000820 \end{array}$$

Length of a quadrant of the meridian $= 10001888^m$

6. *Length of* 1′ *on the surface of a sphere whose radius* $= \frac{1}{2}(a+b)$:

$R = \frac{1}{2}(a+b) = 6367395^m$

$$\begin{array}{ll} \log = & 6.8039618 \\ \log 1' & 6.4637261 \\ \hline & 3.2676879 \end{array}$$

$$\text{Length of } 1' = \overset{m.}{1852.200} = \overset{feet.}{6076.82}$$

7. *Length of 1′ on a sphere, the radius of which is equal to the average radius of curvature of the meridian, the radii of curvature being at equal angular intervals:*

$$\begin{array}{lrr} & \textit{m.} & \\ R = \frac{1}{2}(a+b) + \frac{1}{16}ac^2 & 1852.200 & \\ + \frac{1}{16} \times 0.0213 & +\ 0.001 & \\ \hline & & \textit{feet.} \\ \text{Length of } 1' = & 1852.201 = & 6076.82 \end{array}$$

This is identical with the length of a quadrant of the meridian divided by 5400.

8. *Length of 1′ on the surface of a sphere, the area of a great circle of which is equal to the area of the plane of the meridian of the spheroid:*

$$\begin{array}{lrr} & \textit{m.} & \\ R = \sqrt{ab} = \frac{1}{2}(a+b) - \frac{1}{8}ac^2 & 1852.200 & \\ - \frac{1}{8} \times 0.0213 = & -\ 0.003 & \\ \hline & & \textit{feet.} \\ \text{Length of } 1' = & 1852.197 = & 6076.82 \end{array}$$

9. *Length of 1′ on a sphere, the surface of which is equal to the surface of the earth:*

$$\begin{array}{lrr} R = \frac{1}{3}(2a+b) - \frac{1}{45}ac^2,\ \frac{1}{3}(2a+b) = 6370999 & \log & 6.8042075 \\ & \log 1' & 6.4637261 \\ \hline [\frac{1}{45} + \times 0.0213 = 0.0004] & & 3.2679336 \end{array}$$

$$\begin{array}{lrr} & \textit{m.} & \textit{feet.} \\ \text{Length of } 1' = & 1853.248 = & 6080.27 \end{array}$$

10. *Length of 1′ on a sphere, the volume of which is equal to the volume of the earth:*

$$\begin{array}{lrr} & \textit{m.} & \\ R = \sqrt[3]{a^2b} = \frac{1}{3}(2a+b) - \frac{1}{9}ac^2 & 1853.248 & \\ - \frac{1}{9} \times 0.0213 & -\ 0.002 & \\ \hline & & \textit{feet.} \\ \text{Length of } 1' = & 1853.246 = & 6080.26 \end{array}$$

RECAPITULATION.

| | Meters. | Feet. |
|---|---|---|
| Length of 1′ on the equator | 1855. 345 | 6087. 15 |
| Length of 1′ of latitude at the equator | 1842. 787 | 6045. 95 |
| Length of 1′ of latitude at the pole | 1861. 655 | 6107. 85 |
| Length of 1′ of latitude for latitude 45° | 1852. 181 | 6076. 76 |
| LENGTH OF 1′ ON THE SURFACE OF A SPHERE. | | |
| Radius equal to the mean of the semi-axes of the earth | 1852. 200 | 6076. 82 |
| Area of a great circle equal to area of plane of meridian of the earth | 1852. 197 | 6076. 82 |
| Radius equal to average radius of curvature of meridian of the earth | 1852. 201 | 6076. 82 |
| Surface equal to the surface of the earth | 1853. 248 | 6080. 27 |
| Volume equal to the volume of the earth | 1853. 246 | 6080. 26 |

# APPENDIX No. 13.

## ON A METHOD OF READILY TRANSFERRING THE UNDERGROUND TERMINAL MARKS OF A BASE LINE.

By O. H. TITTMANN, Assistant.

As a base line monument whose foundation is near the surface of the ground is liable to disturbance by frost, the ultimate point of reference is usually an underground mark. The customary arrangement of the surface marks, forming a superstructure to the underground mark, makes it difficult to refer to the latter. The usual method of referring one to the other is to excavate trenches in line between the lower marks and a theodolite mounted at some distance from it, so that it is visible in the telescope of the theodolite, which is adjusted to describe a vertical plane at right angles to the line of measurement.

When it was desired to place the permanent marks at the termini of the Trial Base at Fort Myer, Virginia, suggestions as to the best method of accomplishing the desired end were invited by Mr. Hilgard, the assistant in charge of the office, under whose direction the operations of the measuring and marking were executed. The following plan, submitted by the writer, was approved and adopted.

The essential features of the plan are as follows: A stable underground mark is placed below the frost line.* Over this mark is set an earthenware pipe, which extends upwards into and through a hollow surface pier, from which, however, it is entirely disconnected. The foundation of the surface pier is separated from the underground mark by a depth of several feet of earth, by which the earthenware tube is held firmly in position. The tube is protected against the weather by means of a capstone, removable at pleasure. Terminal surface marks are made on the pier, below the capstone, in the line of the base and at known distances from the vertical plane, passing through the underground mark at right angles to the line of the base.

To refer the lower mark to the surface a vertical collimator is used. This consists of a telescope, having an eye-piece filar micrometer and carrying a delicate level, and which revolves about a vertical axis passing through a small tripod stand furnished with leveling screws. The underground mark is rendered visible by means of natural or artificial light reflected downwards by a mirror.

The line of collimation of the telescope, being placed in the vertical of the underground mark, serves as the initial point in the measurement of the base.

Under the direction of Mr. Hilgard the details of the collimator were arranged by Mr. Saegmuller, chief mechanician. As constructed, it consists of a brass plate about 14 centimeters in diameter, supported on three leveling screws. The upper surface is turned out so as to leave a rim about 5 millimeters deep and 10 millimeters thick, through which four counter screws pass. The counter screws press against the beveled edge of the circular plate which forms the base of a hollow column in which the telescope revolves about its vertical axis. Attached to the telescope is a delicate level with a scale, 1 millimeter of which has an angular value of about 2″. The ocular can be adjusted to different foci by the usual rack and pinion movement, and has a filar micrometer. The telescope has a collar, concentric with its axis, carrying, at opposite ends of that diameter which is at right angles to the micrometer thread, two polished steel surfaces, against which the contact slide of the base bars is intended to abut at the beginning of or during the measurement when it is desired to refer the end of a base bar to a temporary mark in the ground. Its construction having been sufficiently explained, it remains to point out the manner in which it is to be used

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* At Greenwich the lowest temperature marked by a thermometer 6.4 feet below the surface of the ground is about 9° Fahr. above the mean temperature of the coldest month in the year. If the same difference holds at Washington, a corresponding depth would give a minimum temperature of about 43° Fahr.

*In transferring an underground mark to the surface.*—By means of a small mirror light is reflected upon the underground mark. The collimator is mounted as nearly as may be over the mark, with one of the leveling screws in the direction of the line of measurement. The micrometer thread is set to the reading of the line of collimation. The telescope is made vertical by means of the leveling screws, and the intersection of the cross threads is brought over the underground mark, as nearly as may be, by moving the telescope by means of the counter screws, the verticality of the telescope being carefully preserved. Several pointings on the underground mark are then made by means of the filar micrometer, and its reading and that of the level are recorded. The telescope is then revolved 180°, and the operation of pointing on the mark and reading the level is repeated. From these readings the horizontal distance of the line of collimation from the underground mark becomes known in terms of the micrometer. If, as originally contemplated, the underground mark is a line ruled between two others at known distances from it, a measurement of these distances will at once give the value of the micrometer in absolute measure. It is, however, practicable to determine the values of the micrometer for different distances between a mark and the objective, and these having been tabulated will furnish by interpolation the value for any distance between the determined limits, and to this or some other method recourse must be had if there is but one terminal line.

One-half of the diameter of the collar between the abutting surfaces will be the horizontal distance of the latter from the line of collimation. The distance between the line of collimation and the mark having become known by the observations above described, we have an abutting surface at a known distance from the mark, from which the measurement may proceed.

*To transfer the end of a bar to a surface-mark during the measurement of a base line.*—The collimator is mounted on an adjustable tripod in front of the base bar at nearly the requisite height, and within a few millimeters in horizontal distance. By means of the leveling screws the height of the abutting surfaces of the collar is made to correspond to that of the bar, the telescope is made vertical, and by using the counter screws contact between the respective abutting surfaces, of the bar and telescope is effected.

The micrometer thread having been put in the line of collimation and the telescope focused, a mark is made in the line of sight on the reference steel. The position of the mark with reference to the collimation may be tested by sighting upon it after the telescope has been revolved 180°.

In resuming the measurement the collimator is established over the reference mark. The rear bar is put up in position in contact with the collimator. The latter is taken away, and the measurement continued by using the forward end of the rear bar as the initial point.

# APPENDIX No. 14.

## ON THE FLEXURE OF PENDULUM SUPPORTS.

By C. S. PEIRCE, Assistant.

### HISTORICAL.

The fact that the rate of a pendulum might be largely influenced by the elastic yielding of its support was first pointed out by Dr. Thomas Young in his article on Tides in the Encyclopædia Britannica, where he gave a correct mathematical analysis of the problem. Kater made use of the *noddy*, or inverted pendulum of Hardy, to assure himself that its support was sufficiently steady.

Hardy's noddy is a pendulum turning with a reed spring and provided with an adjustable bob. It differs from an ordinary pendulum, first, in being upside down, that is, having its center of mass above its point of support; and second, in having a spring so strong as to act a little more strongly than gravity. The force tending to bring the pendulum to the vertical is then the excess of the force of the spring over the moment of gravity. In this way the noddy is easily adjusted so as to have the same period of oscillation as the pendulum used to determine gravity, while its moment of inertia is very small. In a note at the end of this paper I give the mathematical analysis of this state of things, from which it will be seen that Kater might have constructed his noddy in such a manner as to detect any amount of flexure sufficient to have a serious effect upon the period of his pendulum.

Bessel, at the end of §3 of his great memoir on the length of the seconds' pendulum at Königsberg, states that he also used Hardy's noddy, and that he swung his pendulum again after stiffening the support. He adds that the effect on the period would probably be the same for his long pendulum as for his short one—a very just remark—which made it less necessary for him to attend to the rigidity of the stand.

The construction of English pendulum supports, that of Bassevi, for example, shows that in that country this source of error was never overlooked. It is noticed even in brief accounts in English of the process of measuring gravity. Thus, a writer in the Encyclopædia Britannica proposed to make use of two different reversible pendulums of the same form but of different weights, in order to take account of the flexure, an idea lately borrowed by M. Cellerier.

When the reversible pendulum came into use the study of the writings of the older observers seems to have been neglected,* and the grave errors due to flexure were never suspected until Albrecht found a value of gravity at Berlin differing by nearly 2 millimeters from that of Bessel. So little was the true cause of this discrepancy at first suspected that it was paradoxically attributed to the neglect of a buoyancy correction.

In 1875, however, General Baeyer gravely suspected that the period of a pendulum swinging upon a Repsold tripod was affected by the oscillation of the latter, and in a circular addressed to the members of the committee on the pendulum of the International Geodetic Congress, he wrote: "The necessity of suspending the pendulum from a stand is a source of error, since a pendulum swinging on a stand sets the latter into oscillation and so influences the rate of the former. The effect could be diminished by the use of a shorter pendulum and smaller stand; but whether it would be rendered entirely insensible is open to question."

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*Thus, Bessel's idea of directly measuring the position of the center of mass was supposed by the Swiss *savans* to belong to M. Cellerier.

It was at this time that I first received the Repsold apparatus from the makers, of whom it had been ordered two years before, on the occasion of my first being charged with the pendulum operations of the Coast Survey. Becoming acquainted with General Baeyer's doubts, I determined to settle the question by measuring the flexibility of the Repsold tripod at the earliest opportunity. This I did at Geneva, where, though I only made a rough measurement, I found that the flexure was fully sufficient to account for the discrepancy between the determinations of Bessel and of Albrecht.

On September 25 of the same year I communicated my result to the standing committee of the Geodetical Congress. At the same sitting the reports of the different members of the pendulum committee were read. Dr. Bruhns said: "The question whether the stand is set into oscillation, and whether the rate of the pendulum is influenced thereby is, in my opinion, well worth investigation. But I should suppose that the stand could be made so stiff as to eliminate this source of error for a pendulum used only as a relative instrument." The views of M. Hirsch, who is so much occupied with the going of time-keepers, are interesting. He said: "The fear that the tripod of suspension may also enter into oscillation, unless it be a fact established by direct observations, seems to me unfounded. Indeed, it cannot be supposed that there are any true oscillations of a body of such a form resting on three points. Besides, the movement of the pendulum whose mechanical moment (*moment mécanique*) is slight on account of its small velocity, could only be communicated to the tripod by the friction of the knife on the supporting plane. Now, this friction is insignificant, as the slowness of the decrement of the amplitude shows, this being almost entirely due to the resistance of the air." It may be observed that the rolling friction of the knife edge is, in truth, very slight, but the amount of the sliding friction is sufficient to hold the knife in place on the supporting plane. Dr. von Oppolzer, the designer of the Repsold tripod in its definitive form, said that the construction of the stand rendered any serious flexure *a priori* improbable; but he did not support this opinion by any calculations.

During the spring of 1876, having already measured the flexibility of the tripod in Paris, I remeasured it in Berlin, where my experiments were witnessed by General Baeyer and a party of gentlemen attached to the Prussian Survey.

In October, 1876, at the meeting of the standing committee of the International Geodetical Union at Brussels, the result of my experiments was announced by General Baeyer. M. Hirsch described certain experimental researches undertaken by him to ascertain whether there was any such flexure in the case of the Swiss tripod. He had, in the first place, employed an extremely sensitive level, which had not entered into oscillation while the pendulum was swinging upon it. It is not clear why M. Hirsch employed a very sensitive level, the natural time of oscillation of which would differ much more from the period of the pendulum than that of a less sensitive level would do. He also used an artificial horizon in the same way. M. Hirsch's conclusion is that "there remains no doubt that the Swiss stand is free from every trace of such oscillations." Dr. von Oppolzer entirely agreed with the views of M. Hirsch.

In the following summer I addressed to M. Plantamour a paper upon the subject, to be submitted to the next meeting of the Geodetical Congress. In this note, which is reprinted at the end of the present report, I first give a mathematical analysis of the problem. I next show experimentally that the motion of the knife-edge support is not a translation, but is a rotation, so that different parts of the head of the tripod, only a few centimeters distant from one another, move through very different distances. Consequently, measures of the flexure made anywhere except at the center of the knife-edge plane require an important correction before they can be used to correct the periods. This is confirmed by experiments with a mirror while the pendulum is in motion. I next give a brief *résumé* of my statical measures of the flexure. I then give measures of the actual flexure under the oscillation of the pendulum, and show that the statical and dynamical flexibilities are approximately equal. Finally, I swing the same pendulum upon the Repsold support and upon another having seven times the rigidity of that one, and I show that the difference of the periods of oscillation agrees with the theory.

Immediately upon the reception of my manuscript, MM. Hirsch and Plantamour commenced new researches, designed to form an "étude approfondie de ce phénomène." These were embodied in a paper by M. Plantamour, which was read to the Geodetical Congress, and which has since been expanded into a memoir entitled "Recherches expérimentales sur le mouvement simultané d'un pendule et de ses supports." M. Plantamour finds fault with me, first, for having measured the flexure with a force five or ten times that of the deflecting force of the pendulum; and second, for measuring the elasticity statically instead of dynamically. The reply to the first objection is that the properties of metals are known to a great extent, that elasticity is not "une force capricieuse," and that no fact is better established than that an elastic strain is proportional to the stress up to near the limit of elasticity, which limit was not approached in the author's experiments. As to the second objection, I had shown by experiment that the statical and dynamical flexures are nearly equal; and I am willing to leave it to time to show whether this will not be assumed in future measures of the flexure of future pendulum supports. M. Plantamour caused a fine point fixed into the head of the tripod to press against a little mirror, mounted on an axis; and then observed the reflection of a scale in a telescope. The length of the path of light from the scale to the telescope divided by the distance of the bearing point from the axis of the mirror he calls the *grossissement;* so that had he used a fixed star in place of his scale, the *grossissement* would have been virtually infinite. From the given length of the lever it would appear that a movement of $0^{\mu}.03$ in the point would turn the mirror 4″. The aperture of the mirror is not stated, but it cannot be supposed that the error of observation would be less than this. It does not seem to me that the use of this mode of measurement, which magnifies the motion but little more than my method, is conducive to accuracy, especially in investigating the difference between statical and dynamical flexure. A certain finite force presses together the point and the lever. Dividing this force by the minute area of pressure, we find the pressure upon the metal is very great, approaching the crushing pressure. Now, the behavior of metals under great pressure is greatly influenced by the time. But my objection is not merely theoretical; I have myself made experiments upon this method, and, making them as skillfully as I could, I still found great uncertainty in the results.

The following table exhibits M. Plantamour's results:

*M. Plantamour's flexure experiments.*

| | Flexure under swinging pendulum. | Flexure when weight is raised and lowered. | Statical flexure. |
|---|---|---|---|
| | μ | μ | μ |
| Support on floor, comparator removed | 3.26 ± .05 | 3.17 ± .09 | 3.27 ± .04 |
| On Geneva pier, comparator removed | 3.17 ± .03 | 3.29 ± .08 | 3.48 ± .04 |
| On Geneva pier, comparator in place | 2.41 ± .06 | 2.50 ± .05 | 2.76 ± .04 |
| On Berlin pier, comparator in place | 2.51 ± .05 | 2.90 ± .04 | 3.24 ± .03 |
| On wooden table, comparator in place | 3.19 ± .03 | 3.26 ± .04 | 3.67 ± .02 |
| On wooden table, comparator removed | 4.42 ± .13 | 4.53 ± .04 | 4.98 ± .05 |
| Excess: | | | |
| Geneva pier over floor | − .09 ± .06 | + .12 ± .12 | + .21 ± .06 |
| Berlin over Geneva pier | + .10 ± .08 | + .40 ± .06 | + .48 ± .05 |
| Table over Geneva pier, comparator in place | + .78 ± .07 | + .76 ± .06 | ± .91 ± .04 |
| Table over Geneva pier, comparator removed | +1.16 ± .14 | +1.36 ± .10 | +1.71 ± .06 |
| Effect of comparator: | | | |
| Geneva pier | − .76 ± .07 | − .79 ± .09 | − .72 ± .06 |
| Table | −1.23 ± .14 | −1.27 ± .06 | −1.31 ± .05 |
| Excess table over pier | − .47 ± .16 | − .48 ± .11 | − .59 ± .08 |

The table used is the same one shown in Fig. 26 of the Coast Survey Report for 1877. The numbers in the last line above should show the effect of the weight of 3 kilogrammes in diminishing the flexure of this table under a horizontal force of 100 grammes. The weights used in obtaining the first two numbers were about 100 grammes; but the last column is one-tenth the deflection produced by 1,000 grammes. It seems quite incredible that 3 kilogrammes, laid on the table, should really have an effect of this magnitude, so closely proportionate, too, to the deflecting force. It is highly desirable that this result should be confirmed by purely optical experiments; and until this is done, we must suspect that these large numbers indicate some error to which the method of observation is liable. It is certain that the comparator did not act as a brace to stiffen the instrument, and equally so that its weight is not sufficient to alter the modules of elasticity of the brass of the support. It would seem, however, that the effect might be due to a film of some semi-elastic substance under the feet of the tripod. When the tripod is on the floor, no such effect is observed; when it rests on the Geneva pier the dynamical flexure is the same as when it is on the floor, but the statical flexure is much larger. On the Berlin pier the excess of the statical flexure over that on the Geneva pier is five times the dynamical excess. On the other hand, the excess of the dynamical flexure on the table over that at Berlin is half as great again as the statical excess.

## MEASURES OF FLEXURE.

My own measures form two series, those made previous to, and those made subsequent to the publication of M. Plantamour's memoir.

In the first series, I was simply occupied in measuring the flexure of the Repsold tripod, as well when properly put up as when the nuts of the bolts were not tightened, of the Geneva support as mounted at Hoboken, and of my "stiffest" support. All the precise measures are statical, and, being made with a filar micrometer, are superior in accuracy to the subsequent ones.

In the second series, the flexures are always measured dynamically as well as statically, and the statical flexure is always found to be the greatest. On the excessively flexible Repsold tripod the difference is sufficient to affect the length of the second's pendulum by $10^{\mu}$. Nevertheless, as the axis of motion is different for the two kinds of flexure, there are points at which the motion is *less* for dynamical than for statical flexure. And in point of fact, when the Geneva support rests on the Geneva tripod, the dynamical flexure of the center of the knife-edge is *greater* than the statical flexure.

Experiments were also made upon the effect of leaving the nuts of the Repsold tripod entirely loose, of tightening them as much as possible by the hand, and of tightening them by a wrench. It is found that there is little difference between leaving them loose and tightening them by hand, but the effect of the wrench is to produce a stiffening equivalent to a shortening of the pendulum by 20 microns.

Experiments were also made upon the effect of placing a weight of 6 pounds, and afterwards of 25 pounds, upon the head of the Repsold support. The first weight produced absolutely no effect; the second moved the axis of motion a little, and thus caused a slight difference of flexure at some points.

Experiments were also made upon the effect of resting the Repsold support upon blotting-paper, upon blocks of oak, and upon blocks of india-rubber. In every case the difference between the statical and dynamical flexure was much increased.

The pendulum has also been *swung* on all these different supports and the period of oscillation determined with a view of ascertaining whether the statical or dynamical flexure should be used in calculating the corrections to the periods. The result, as might have been predicted from the mathematical theory, shows that a value intermediate between the two is to be taken. But the best way is to make the support so solid that the difference of the two kinds of flexure must be inconsiderable.

## EXPERIMENTS TO DETERMINE THE FLEXURE-CORRECTION.

### A.—*Flexure of the Repsold stand.*

To determine the flexure, a known force was applied statically to the stand, and the resulting deflection was measured. The principal experiments were made in the cellar of the Stevens Institute at Hoboken. The floor of the cellar is of brick laid down in cement directly on the solid ledge. The floor having been carefully cleaned, the three brass pieces which support the screw-feet of the Repsold tripod were laid down upon it, and the tripod itself was set up. The binding-screws of the feet were screwed up very tight. The pendulum, comparator, and meter were not placed on the tripod, but a mass of iron about equal to them in weight was placed on blocks on the lower part of the tripod in order to ballast it. To apply the force, a silken cord was wound round the tongue upon which the pendulum usually rests, just in the slot over which is the middle of the knife-edge, in such a manner that the cord when stretched horizontally was exactly at the level of the knife-edge. The cord passed horizontally and perpendicular to the knife-edge to a pulley-wheel over which it passed, and from which it hung down vertically; and to its extremity was attached a kilogramme. The pulley-wheel was one which belonged to an Atwood's machine; it turned with very little friction and its rim was accurately plane and perpendicular to the axis. This wheel rested on a stout wooden tripod; its axis was carefully adjusted to be parallel to the knife-edge and the upper part of the rim was brought to the level of the knife-edge. The usual position of the knife-edge is here referred to; but the pendulum was not actually in position. In the measurements of flexure, one person gently raised and lowered this weight alternately. The measurement of the deflection was made by another person, as follows: A micrometer scale on glass was fixed, either to the tongue or to an arm solidly fixed to the tongue, in such a way that the direction of measurement was parallel to the force applied to the tripod. This micrometer scale was observed by a microscope magnifying about fifty diameters and provided with a filar micrometer. This microscope was mounted on a separate, very stiff, iron stand resting on the floor, and carrying at its head a brass apparatus for holding the microscope. The optical axis of the microscope was made exactly parallel to the knife-edge and the filar micrometer screw was made parallel to the force applied to the stand, and the microscope was focused on the micrometer scale. Each division of the scale usually employed was about $12^{\mu}$. The filar micrometer wire (which was vertical) was made to bisect one division of the scale and the micrometer was read; it was then made to bisect another division, by turning the screw through about one revolution, and the micrometer was read again. Thus, the value of the revolution was obtained. The weight was then put on, and pointings were made upon the same two divisions. Then, the whole process was repeated until the weight had been put on five times. This made one set of experiments.

The following experiments were made to determine the position of the axis of rotation of the knife-edge support during flexure.

HOBOKEN, *March* 10, 1877. Ther. 13° C.—The micrometer scale, attached to an arm, was placed on the line of the knife-edge $53^{mm}$ in front of the anterior extremity of the tongue. The following were the readings of the filar micrometer on one of the lines of the scale with the weight alternately on and off ($\rho$ throughout signifies a revolution of the micrometer screw):

| | Weight off. | Weight on. |
|---|---|---|
| | $\rho$ | $\rho$ |
| | 10.955 | 11.324 |
| | .968 | .320 |
| | .978 | .324 |
| Means.... | 10.967 | 11.323 |

Difference, $+0^{\rho}.356$.

The arm was now lengthened so that the scale was $318^{mm}$ in front of the end of the tongue. The following readings of the filar micrometer were now made:

| | Weight off. | Weight on. |
|---|---|---|
| | $\rho$ | $\rho$ |
| | 10.344 | 10.762 |
| | .350 | .776 |
| | .341 | .793 |
| | .335 | .778 |
| | .330 | .772 |
| Means.... | 10.340 | 10.776 |

Difference, $+0^{\rho}.436$.

The micrometer-scale was next carried over to the other side of the instrument so as to be $496^{mm}$ behind the front end of the tongue. The following readings were now made:

| | Weight off. | Weight on. |
|---|---|---|
| | $\rho$ | $\rho$ |
| | 10.106 | 10.324 |
| | .120 | .334 |
| | .141 | .334 |
| | .124 | .346 |
| | .136 | .340 |
| Means.... | 10.125 | 10.336 |

Difference, $+0^{\rho}.211$.

It will be understood that in all these experiments the arm to which the scale was fixed was attached to the tongue on which the pendulum rests, and that this arm was subjected to no force.

The above results are satisfied by supposing that the axis of rotation cuts the level of the knife-edge $1^{m}.258$ behind the end of the tongue. The following table shows the agreement of the observations with this supposition.

| Distance forward of end of tongue. | Flexure. Obs. | Flexure. Calc. |
|---|---|---|
| $m$ | $\rho$ | $\rho$ |
| +0.318 | 0.436 | 0.433 |
| +0.053 | 0.356 | 0.361 |
| −0.496 | 0.211 | 0.212 |

The scale was next (March 12, 1877, observer, Edwin Smith) fixed at $395^{mm}$ vertically below the end of the tongue. The following measures were then made:

| | Weight off. | Weight on. |
|---|---|---|
| | $\rho$ | $\mu$ |
| | 13.739 | 13.260 |
| | .700 | .247 |
| | .710 | .261 |
| | .700 | .260 |
| | .702 | .243 |
| | .710 | ...... |
| Means.... | 13.710 | 13.254 |

Flexure, $+0^{\rho}.446$.

The filar micrometer was here in the reverse position from its usual one, and hence the reading with weight off is greater than with weight on.

The scale was next placed $44^{cm}$ above the point of support and the following measures were made:

| Weight off. | Weight on. |
|---|---|
| $\rho$ | $\rho$ |
| 10.523 | 10.737 |
| .453 | .645 |
| .400 | .578 |
| 10.459 | 10.653 |

Deflection, $-0^{\rho}.196$.

The filar micrometer was so shaky in this position that accurate measures could not be obtained, but the above answers the purpose.

The scale was next fixed on the end of the tongue and the three measures given below (series 18, 19, 20) were made. The mean of these gives a flexure of $0^{\rho}.340$. These measures show that the axis of rotation cuts a vertical from the end of the tongue at a height of 1.07 meters above the level of the knife-edge. Thus we have on this hypothesis:

| Distance below knife-edge. | Flexure. Obs. | Flexure. Calc. |
|---|---|---|
| m | ρ | ρ |
| −0.44 | 0.196 | 0.196 |
| 0.00 | 0.340 | 0.332 |
| +0.395 | 0.446 | 0.452 |

A large series of experiments were made at Hoboken to determine the amount of flexure. Of these, the following are chiefly relied upon:

HOBOKEN, *March* 7, 1877. Ther., 59°.15 F. $3^h\ 12^m$ P. M.

Möller's glass scale of hundredths of millimeters was fixed 3 millimeters above the end of the tongue. The filar micrometer wires remained fixed, and readings of the micrometer scale were made on the two wires, alternately with weight off and on.

FIRST SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | μ | μ | μ | μ |
| | 844 | 893 | 878 | 931 |
| | 843 | 894 | 879 | 930 |
| | 844 | 894 | 879 | 931 |
| | 845 | 895 | 879 | 930 |
| | 844 | 896 | 879 | 931 |
| Means, | 844.0 | 894.2 | 878.8 | 930.4 |

Distance of wires, $\overset{\mu}{50}.2$ $\overset{\mu}{51}.6$

Flexure, $\overset{\mu}{34}.4$ $\overset{\mu}{36}.2$

Mean, $\overset{\mu}{35}.3$

The following readings were then taken with the filar micrometer (temperature 59°.24 F.). The wire was set between lines 80 and 81, and between lines 90 and 91 of the scale.

SECOND SERIES.

| | Weight off. 90–91 | Weight off. 80–81 | Weight on. 90–91 | Weight on. 80–81 |
|---|---|---|---|---|
| | ρ | ρ | ρ | ρ |
| | 9.347 | 10.312 | 9.694 | 10.655 |
| | 344 | .309 | .693 | .660 |
| | 348 | .315 | .692 | .664 |
| | 348 | .322 | .699 | .663 |
| | 352 | .336 | .713 | .684 |
| Means, | 9.344 | 10.319 | 9.698 | 10.665 |

$\frac{1}{10}$ millimeter, $0.\overset{\rho}{9}75$ $0.\overset{\rho}{9}67$

Flexure, $0.\overset{\rho}{3}54$ $0.\overset{\rho}{3}46$

Mean, $0.\overset{\rho}{3}50 = \overset{\mu}{36}.1$

This last set was considered of inferior accuracy.

HOBOKEN, *March* 10, 1877. $0^h\ 15^m$ P. M. Temp., 11°.9 C.

A scale on glass by Rogers was observed in the same position as above. Each division is $\frac{1}{2000}$ of an inch ($=127^\mu$). The micrometer wire was placed between the first and second and between the tenth and eleventh lines. The observations were made alternately with the weight off and on.

THIRD SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2 | 10–11 | 1–2 | 10–11 |
| | $9.\overset{\rho}{715}$ | $10.\overset{\rho}{849}$ | $10.\overset{\rho}{060}$ | $11.\overset{\rho}{193}$ |
| | .720 | .855 | .058 | .185 |
| | .723 | .845 | .049 | .186 |
| | .715 | .846 | .055 | .185 |
| | .714 | .841 | .050 | .176 |
| Means, | 9.719 | 10.847 | 10.054 | 11.185 |

$\frac{9}{2000}$ inch, $1.\overset{\rho}{128}$ $1.\overset{\rho}{131}$ $\therefore \frac{1}{10}$ mm.$=0.\overset{\rho}{988}$

Flexure, $0.\overset{\rho}{335}$ $0.\overset{\rho}{338}$

Mean, $0.\overset{\rho}{336}=\overset{\mu}{34}.1$

This series occupied seven minutes. The whole apparatus was readjusted and a new set was made, as follows:

FOURTH SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2 | 10–11 | 1–2 | 10–11 |
| | $9.\overset{\rho}{117}$ | $10.\overset{\rho}{239}$ | $9.\overset{\rho}{459}$ | $10.\overset{\rho}{580}$ |
| | .122 | .236 | .449 | .586 |
| | .125 | .241 | .464 | .581 |
| | .120 | .244 | .456 | .584 |
| | .128 | .234 | .456 | .579 |
| Means, | 9.122 | 10.239 | 9.457 | 10.582 |

$\frac{9}{2000}$ inch, $1.\overset{\rho}{117}$ $1.\overset{\rho}{125}$ $\therefore \frac{1}{10}$ mm.$=0.\overset{\rho}{982}$

Flexure, $0.\overset{\rho}{335}$ $0.\overset{\rho}{343}$

Mean, $0.\overset{\rho}{339}=\overset{\mu}{34}.5$

At $2^h$ $55^m$ P. M. another set of experiments were made, giving the following results (temperature, 12°.2 C.):

FIFTH SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2 | 10–11 | 1–2 | 10–11 |
| | $9.\overset{\rho}{641}$ | $10.\overset{\rho}{745}$ | $9.\overset{\rho}{980}$ | $11.\overset{\rho}{082}$ |
| | .619 | .748 | .968 | .084 |
| | .612 | .745 | .962 | .075 |
| | .616 | .735 | .963 | .089 |
| | .626 | .754 | .976 | .104 |
| Means, | 9.623 | 10.745 | 9.970 | 11.087 |

$\frac{9}{2000}$-inch, $1.\overset{\rho}{122}$ $1.\overset{\rho}{117}$ $\therefore \frac{1}{10}$ mm.$=0.\overset{\rho}{980}$

Flexure, $\overset{\rho}{0}.347$ $\overset{\rho}{0}.342$

Mean, $0.\overset{\rho}{344}=\overset{\mu}{35}.1$

After this set the focus was readjusted and two more sets were taken, as follows (temperature, 12°.2):

SIXTH SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2 | 10–11 | 1–2 | 10–11 |
| | $\overset{\rho}{9.600}$ | $\overset{\rho}{10.730}$ | $\overset{\rho}{9.953}$ | $\overset{\rho}{11.083}$ |
| | .602 | .742 | .956 | .080 |
| | .605 | .736 | .945 | .075 |
| | .594 | .740 | .953 | .076 |
| | .602 | .734 | .951 | .071 |
| Means, | 9.601 | 10.736 | 9.952 | 11.077 |

$\frac{9}{2000}$-inch, $\overset{\rho}{1.135}$ $\overset{\rho}{1.125}$ ∴ $\frac{1}{10}$ mm.$=\overset{\rho}{0.989}$

Flexure, $\overset{\rho}{0.351}$ $\overset{\rho}{0.341}$

Mean, $\overset{\rho}{0.346}=\overset{\mu}{35.0}$

SEVENTH SERIES.

Temp., 13° C.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2. | 10–11. | 1–2. | 10–11. |
| | $\overset{\rho}{9.582}$ | $\overset{\rho}{10.711}$ | $\overset{\rho}{9.929}$ | $\overset{\rho}{11.046}$ |
| | .575 | .706 | .921 | .040 |
| | .570 | .703 | .922 | .042 |
| | .575 | .700 | .918 | .038 |
| | .561 | .697 | .912 | .033 |
| Means, | 9.573 | 10.703 | 9.920 | 11.040 |

$\frac{9}{2000}$ inch, $\overset{\rho}{1.130}$ $\overset{\rho}{1.120}$ ∴ $\frac{1}{10}$ mm.$=\overset{\rho}{0.984}$

Flexure, $\overset{\rho}{0.347}$ $\overset{\rho}{0.337}$

Mean, $\overset{\rho}{0.342}=\overset{\mu}{34.8}$

Three sets were then taken, placing the micrometer wire between the second and third lines, instead of the first and second. The light had now become fainter. Temp., 13°.1 C.

EIGHTH SERIES.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 2–3. | 10–11. | 2–3. | 10–11. |
| | $\overset{\rho}{9.710}$ | $\overset{\rho}{10.724}$ | $\overset{\rho}{10.061}$ | $\overset{\rho}{11.061}$ |
| | .712 | .721 | .057 | .059 |
| | .719 | .711 | .052 | .053 |
| | .713 | .721 | .052 | .058 |
| | .725 | .727 | .060 | .055 |
| Means, | 9.716 | 10.721 | 10.056 | 11.057 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.005}$ $\overset{\rho}{1.001}$ ∴ $\frac{1}{10}$ mm.$=\overset{\rho}{0.987}$

Flexure, $\overset{\rho}{0.340}$ $\overset{\rho}{0.336}$

Mean, $\overset{\rho}{0.338}=\overset{\mu}{34.2}$

After this set the focus was changed. Thermometer still 13°.1 C.

NINTH SERIES.

| | Weight off. | | Weight on. | | |
|---|---|---|---|---|---|
| | 2–3. | 10–11. | 2–3. | 10–11. | |
| | ρ | ρ | ρ | ρ | |
| | 9.669 | 10.677 | 10.027 | 11.022 | |
| | .696 | .696 | .030 | .035 | |
| | .696 | .693 | .039 | .045 | |
| | .694 | .695 | .032 | .038 | |
| | .685 | .693 | .032 | .035 | |
| Means, | 9.688 | 10.691 | 10.032 | 11.035 | |
| $\frac{8}{2000}$ inch, | $\overset{\rho}{1}.003$ | | $\overset{\rho}{1}.003$ | | ∴ $\frac{1}{10}$ mm.=$\overset{\rho}{0}.987$ |
| Flexure, | | $\overset{\rho}{0}.344$ | $\overset{\rho}{0}.344$ | | |
| Mean, | | $\overset{\rho}{0}.344=\overset{\mu}{34}.9$ | | | |

It was noted that this set ought to have double weight. The following set was then taken temperature, 13°.1 C.:

TENTH SERIES.

| | Weight off. | | Weight on. | | |
|---|---|---|---|---|---|
| | 2–3. | 10–11. | 2–3. | 10–11. | |
| | ρ | ρ | ρ | ρ | |
| | 9.688 | 10.689 | 10.019 | 11.029 | |
| | .675 | .674 | .025 | .031 | |
| | .674 | .676 | .014 | .020 | |
| | .670 | .675 | .014 | .020 | |
| | .662 | .660 | .016 | .016 | |
| Means, | 9.674 | 10.675 | 10.018 | 11.023 | |
| $\frac{8}{2000}$ inch, | $\overset{\rho}{1}.001$ | | $\overset{\rho}{1}.005$ | | ∴ $\frac{1}{10}$ mm.=$\overset{\rho}{0}.987$ |
| Flexure, | | 0.344 | $\overset{\rho}{0}.348$ | | |
| Mean, | | $\overset{\rho}{0}.346=\overset{\mu}{35}.1$ | | | |

This set was also assigned double weight at the time.

Collecting the foregoing results, we have for the deflection of the end of the tongue under one kilogramme's weight—

| | | Diff. from mean. |
|---|---|---|
| | μ | μ |
| 1st set, March 7, 1877 | 35.3 | +0.4 |
| 2nd set, March 7, 1877 | 36.1 | +1.2 |
| 3d set, March 10, 1877 | 34.1 | −0.8 |
| 4th set, March 10, 1877 | 34.5 | −0.4 |
| 5th set, March 10, 1877 | 35.1 | +0.2 |
| 6th set, March 10, 1877 | 35.0 | +0.1 |
| 7th set, March 10, 1877 | 34.8 | −0.1 |
| 8th set, March 10, 1877 | 34.2 | −0.7 |
| 9th set, March 10, 1877 | 34.9 | +0.1 |
| 10th set, March 10, 1877 | 35.1 | +0.2 |
| Mean | 34.9 | ±0.1 |

The middle of the knife-edge being $30^{mm}$ behind the end of the tongue, which is $1^{m}.258$ forward of the point where the axis of rotation crosses the knife-edge produced, it follows that $\frac{30}{1258}$ of the flexure observed at the end of the tongue, or $0^{\mu}.8$, has to be subtracted from that quantity to get the flexure of the middle of the edge. The latter is, therefore, $34^{\mu}.1$.

Measures of the flexure were also made on the 8th and 12th of March, by Sub-assistant Edwin **Smith**. The following are his results:

### ELEVENTH SERIES.

$1^h\ 15^m$ p. m. Temp., 60°.41 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 2–3. | 7–9. | 2–3. | 7–9. |
| | ρ | ρ | ρ | ρ |
| | 6.970 | 7.599 | 7.305 | 7.940 |
| | .956 | .571 | .298 | .940 |
| | .963 | .581 | .295 | .930 |
| | .950 | .573 | .281 | .915 |
| Means, | 6.960 | 7.581 | 7.295 | 7.931 |

$\frac{5}{2000}$ inch, $\overset{\rho}{0.621}$ $\overset{\rho}{0.636}$

Flexure, $\overset{\rho}{0.335}$ $\overset{\rho}{0.350}$

Mean, $\overset{\rho}{0.342} = \overset{\mu}{34.5}$

### TWELFTH SERIES.

$1^h\ 45^m$ p. m. Temp., 60°.37 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 2–3. | 10–11. | 2–3. | 10–11. |
| | ρ | ρ | ρ | ρ |
| | 6.921 | 7.930 | 7.245 | 8.256 |
| | .911 | .915 | .248 | .249 |
| | .915 | .917 | .248 | .253 |
| | .906 | .913 | .248 | .248 |
| | .902 | .907 | .247 | .240 |
| Means, | 6.911 | 7.916 | 7.247 | 8.249 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.005}$ $\overset{\rho}{1.002}$

Flexure, $\overset{\rho}{0.336}$ $\overset{\rho}{0.333}$

Mean, $\overset{\rho}{0.334} = \overset{\mu}{33.9}$

### THIRTEENTH SERIES.

$2^h\ 05^m$ p. m. Temp., 60°.52 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 2–3. | 10–11. | 2–3. | 10–11. |
| | ρ | ρ | ρ | ρ |
| | 6.943 | 7.949 | 7.271 | 8.282 |
| | .945 | .946 | .279 | .278 |
| | .941 | .941 | .271 | .275 |
| | .932 | .934 | .270 | .273 |
| | .938 | .939 | .271 | .273 |
| Means, | 6.940 | 7,942 | 7.272 | 8.276 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.002}$ $\overset{\rho}{1.004}$

Flexure, $\overset{\rho}{0.332}$ $\overset{\rho}{0.334}$

Mean, $\overset{\rho}{0.333} = \overset{\mu}{33.7}$

### FOURTEENTH SERIES.

$2^h\ 25^m$ p. m. Temp., 60°.27 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 2-3. | 10-11. | 2-3. | 10-11. |
| | ρ | ρ | ρ | ρ |
| | 6.942 | 7.943 | 7.280 | 8.288 |
| | .939 | .945 | .277 | .287 |
| | .942 | .949 | .281 | .281 |
| | .944 | .950 | .279 | .280 |
| | .940 | .941 | .279 | .283 |
| Means, | 6.941 | 7.946 | 7.279 | 8.284 |

$\frac{8}{2000}$ inch, $1\overset{\rho}{.}005$ $1\overset{\rho}{.}005$

Flexure, $0\overset{\rho}{.}338$ $0\overset{\rho}{.}338$

Mean, $0\overset{\rho}{.}338=34\overset{\mu}{.}2$

### FIFTEENTH SERIES.

$2^h\ 40^m$ p. m. Temp., 60°.23 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1-2. | 9-10. | 1-2. | 9-10. |
| | ρ | ρ | ρ | ρ |
| | 6.825 | 7.825 | 7.159 | 8.159 |
| | .823 | .826 | .159 | .161 |
| | .822 | .829 | .158 | .158 |
| | .819 | .820 | .157 | .160 |
| | .821 | .823 | .157 | .160 |
| Means, | 6.822 | 7.825 | 7.158 | 8.160 |

$\frac{8}{2000}$ inch, $1\overset{\rho}{.}003$ $1\overset{\rho}{.}002$

Flexure, $0\overset{\rho}{.}336$ $0\overset{\rho}{.}335$

Mean, $0\overset{\rho}{.}336=34\overset{\mu}{.}0$

### SIXTEENTH SERIES.

$2^h\ 55^m$ p. m. Temp., 60°.18.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1-2. | 9-10. | 1-2. | 9-10. |
| | ρ | ρ | ρ | ρ |
| | 6.822 | 7.822 | 7.153 | 8.160 |
| | .824 | .826 | .158 | .156 |
| | .826 | .827 | .157 | .158 |
| | .821 | .823 | .160 | .161 |
| | .820 | .823 | .161 | .161 |
| Means, | 6.823 | 7.824 | 7.158 | 8.159 |

$\frac{8}{2000}$ inch, $1\overset{\rho}{.}001$ $1\overset{\rho}{.}001$

Flexure, $0\overset{\rho}{.}335$ $0\overset{\rho}{.}335$

Mean, $0\overset{\rho}{.}335=34\overset{\mu}{.}0$

### SEVENTEENTH SERIES.

$3^h\ 10^m$ p. m. Temp., 60°.04 F.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 1–2 | 9–10 | 1–2 | 9–10 |
| | ρ | ρ | ρ | ρ |
| | 6.850 | 7.847 | 7.172 | 8.175 |
| | .849 | .848 | .179 | .183 |
| | .849 | .852 | .186 | .183 |
| | .849 | .851 | .189 | .190 |
| | .850 | .850 | .180 | .181 |
| Means, | 6.849 | 7.850 | 7.181 | 8.182 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.001}$ $\overset{\rho}{1.001}$

Flexure, $\overset{\rho}{0.332}$ $\overset{\rho}{0.332}$

Mean, $\overset{\rho}{0.332}=\overset{\mu}{33.7}$

### 1877, MARCH 12.

### EIGHTEENTH SERIES.

Ther., 14°.1 C.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 12–13 | 20–21 | 12–13 | 20–21 |
| | ρ | ρ | ρ | ρ |
| | 8.432 | 9.452 | 8.807 | 9.805 |
| | .453 | .467 | .807 | .805 |
| | .448 | .457 | .797 | .801 |
| | .445 | .462 | .792 | .800 |
| | .440 | .450 | .780 | .779 |
| Means, | 8.444 | 9.458 | 8.797 | 9.798 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.014}$ $\overset{\rho}{1.001}$

Flexure, $\overset{\rho}{0.353}$ $\overset{\rho}{0.340}$

Mean, $\overset{\rho}{0.346}=\overset{\mu}{34.9}$

After this the apparatus was readjusted.

### NINETEENTH SERIES.

Ther., 14°.2 C.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 12–13 | 20–21 | 12–13 | 20–21 |
| | ρ | ρ | ρ | ρ |
| | 9.421 | 10.431 | 9.755 | 10.758 |
| | .419 | .435 | .753 | .750 |
| | .421 | .428 | .763 | .770 |
| | .428 | .428 | .757 | .770 |
| | .419 | .423 | .763 | .763 |
| Means, | 9.422 | 10.429 | 9.758 | 10.762 |

$\frac{8}{2000}$ inch, $\overset{\rho}{1.007}$ $\overset{\rho}{1.004}$

Flexure, $\overset{\rho}{0.336}$ $\overset{\rho}{0.333}$

Mean $\overset{\rho}{0.334}=\overset{\mu}{34.0}$

TWENTIETH SERIES.

Ther., 14°.2 C.

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 12–13 | 20–21 | 12–13 | 20–21 |
| | ρ | ρ | ρ | ρ |
| | 9.383 | 10.390 | 9.726 | 10.744 |
| | .400 | .402 | .730 | .738 |
| | .395 | .399 | .728 | .725 |
| | .396 | .405 | .735 | .743 |
| | .398 | .405 | .735 | .730 |
| Means, | 9.394 | 10.400 | 9.731 | 10.736 |
| $\frac{8}{2000}$ inch, | ρ 1.006 | | ρ 1.005 | |
| Flexure, | ρ 0.337 | | ρ 0.336 | |
| Mean, | ρ 0.337=34.1 μ | | | |

During the last two sets the illumination was very poor.

Mr. Smith's results, being collected, are as follows:

| | Flexure. | Difference from the mean. |
|---|---|---|
| | μ | μ |
| 11th set, 1877, March 8 | 34.5 | +0.4 |
| 12th set, 1877, March 8 | 33.9 | −0.2 |
| 13th set, 1877, March 8 | 33.7 | −0.4 |
| 14th set, 1877, March 8 | 34.2 | +0.1 |
| 15th set, 1877, March 8 | 34.0 | −0.1 |
| 16th set, 1877, March 8 | 34.0 | −0.1 |
| 17th set, 1877, March 8 | 33.7 | −0.4 |
| 18th set, 1877, March 12 | 34.9 | +0.8 |
| 19th set, 1877, March 12 | 34.0 | −0.1 |
| 20th set, 1877, March 12 | 34.1 | ±0.0 |
| Mean | 34.1 | ±0.1 |

It will be seen that there is a rather large difference between the results of the two observers. It will, of course, be understood that the discordances of single readings are due mainly to relative movements of the micrometer and the pendulum-support. As most of the sources of constant error tend to make the observed values too small, the larger result has been preferred. When the binding-screws of the feet were not perfectly tight the flexure was still greater, as is shown by the following means of sets of observations made under those circumstances:

| | Flexure. | Diffence from the mean. |
|---|---|---|
| | μ | μ |
| 21st set, 1877, February 17 | 36.5 | −0.4 |
| 22d set, 1877, February 17 | 37.9 | +1.0 |
| 23d set, 1877, February 17 | 36.1 | −0.8 |
| 24th set, 1877, February 17 | 37.8 | +0.9 |
| 25th set, 1877, February 17 | 36.9 | 0.0 |
| 26th set, 1877, February 19 | 35.3 | −1.6 |
| 27th set, 1877, February 19 | 37.6 | +0.7 |
| Mean | 36.9 | ±0.3 |

The flexure of the Repsold stand was also measured in Geneva, Paris, and Berlin. In Berlin the microscope was mounted on a wooden stand, which rested on the same pier as the tripod. This was to avoid including the flexure of the pier, which is best measured separately. The micrometer scale was simply fixed to a piece of wood, which was laid on the brass pieces at the ends of the tongue. This wooden piece projected $35^{mm}$ beyond the tongue, and consequently 1 .7 has to be subtracted from the observed results to get the flexure at the middle of the knife-edge. The following are the means of sets of ten measures:

| | Flexure. | Difference from mean. |
|---|---|---|
| | μ | μ |
| 1876, May 24, a. m | 35. 8 | +0. 1 |
| 1876, May 24, p. m | 35. 7 | 0. 0 |
| 1876, May 24, p. m | 35. 8 | +0. 1 |
| 1876, May 24, p. m | 35. 9 | +0. 2 |
| 1876, May 25, a. m | 35. 5 | −0. 2 |
| 1876, May 25, a. m | 35. 4 | −0. 3 |
| Mean | 35. 7 | ±0. 1 |

This result agrees well with that obtained at Hoboken. Thus:

| | Flexure of middle of knife-edge under 1 kilogramme | $f_0$. |
|---|---|---|
| | μ | μ |
| Hoboken (C. S. P., observer) | 34. 1 | 215. 2 |
| Berlin | 34. 0 | 214. 5 |

The same value was found in a rough measure made at Geneva, September 13, 1875.

Much larger values were obtained in Paris, which agree with those found at Hoboken when the binding-screws were not tight. Thus we have

| | Flexure with binding-screws loose. | |
|---|---|---|
| | μ | |
| Hoboken | 36. 1 | 227. 8 |
| Paris, 1876, January 18 | 36. 3 | 229. 1 |
| Paris, 1876, March 7 | 37. 1 | 234. 1 |

B.—*Flexure of the stiffest support.*

This support was constructed in order to test the calculated effect of the flexure of the stand. The following table shows the results of measures of its flexure:

| Distance of scale forward of center of knife. | Distance of scale below level of knife. | Deflection + in the direction of the force, — in the opposite direction. |
|---|---|---|
| *mm.* | *mm.* | μ |
| + 30 | − 33 | + 5. 2 |
| + 30 | − 33 | + 5. 2 |
| + 30 | +1003 | −42. 5 |
| +335 | +1003 | −36. 7 |

It follows from this that the axis of rotation cuts the line of the knife-edge $166^{mm}$ behind the center of the edge, and cuts the vertical from that center $68^{mm}$ below the edge. Also, that the deflection of the middle of the edge under a force of 1 kilogramme's weight is $3^{\mu}.1$. This includes the flexure of the pier.

C.—*Flexure of the Geneva support and pier.*

In measuring this flexure, instead of a low-power microscope and filar micrometer a high-power microscope and eye-piece micrometer were used. A stage micrometer was always observed, and the value of the divisions of the eye-piece micrometer determined by it. In the following experiments the scale was $254^{mm}$ above the level of the knife-edge and $25^{mm}$ forward of the middle.

## 1878, October 1.

### FIRST SET.

| | Weight off. | Weight on. |
|---|---|---|
| | 10. 4 | 5. 8 |
| | 10. 2 | 5. 6 |
| | 10. 3 | 5. 4 |
| | 10. 2 | 5. 5 |
| | 10. 0 | 5. 4 |
| Means, | 10. 2 | 5. 5 |
| Flexure, | 4. 7 | |

It was observed that 18.5 of eye-piece micrometer equals 9 of stage micrometer. 1 division of latter = $7^{\mu}.34$. ∴ observed flexure = $16^{\mu}.8$.

### SECOND SET.

(Higher power.)

| | Weight off. | | Weight on. | |
|---|---|---|---|---|
| | 12. 4 | 39. 2 | 18. 7 | 45. 8 |
| | 12. 3 | 39. 2 | 19. 0 | 45. 9 |
| | 12. 3 | 39. 3 | 18. 8 | 46. 0 |
| | 12. 4 | 39. 3 | 18. 8 | 46. 1 |
| | 12. 2 | 39. 4 | 18. 7 | 46. 2 |
| Means, | 12. 3 | 39. 3 | 18. 8 | 46. 0 |
| | $66^{\mu}.1$ = 27. 0 | | 27. 2 | ∴ 1 div. = $2^{\mu}.44$ |
| Flexure, | 6. 5 | | 6. 7 | |
| Mean, | 6. 6 = $16^{\mu}.1$ | | | |

### THIRD SET.

| | Weight off. | Weight on. |
|---|---|---|
| | 39. 8 | 46. 4 |
| | 39. 8 | 46. 5 |
| | 39. 9 | 46. 5 |
| | 40. 0 | 46. 6 |
| | 40. 1 | 46. 7 |
| Means, | 39. 9 | 46. 5 |
| Flexure, | 6. 6 | |

Nine spaces of stage micrometer were equal to 27. 1 of eye-piece micrometer. Hence, observed flexure = $16^{\mu}.1$.

### FOURTH SET.

| | Weight off. | Weight on. |
|---|---|---|
| | 39. 9 | 46. 4 |
| | 40. 0 | 46. 6 |
| | 40. 1 | 46. 6 |
| | 40. 0 | 46. 8 |
| | 40. 2 | 46. 8 |
| Means, | 40. 0 | 46. 6 |
| Flexure, | 6. 6 = $16^{\mu}.1$ | |

### 1878, October 19.

The scale was fixed $111^{cm}$ below the knife-edge, and three sets of 10 gave for the deflection

$\mu$.
$-48.8$
$-47.5$
$-48.1$

Mean, $-48.1$

### 1878, October 21.

The scale was fixed 244 millimeters above the knife-edge, and 356 millimeters forward of the middle. Two sets gave as the deflection

$\mu$
$+13.5$
$+12.2$

$+12.8$

From these measures we find the flexure at the middle of the knife-edge to be $4^{\mu}.05$.

## *EXPERIMENTS AT PENNSYLVANIA GRAVITATION STATIONS.*

### Allegheny.

Statical flexure of Geneva support on iron bars. Weight and pulley employed. Weight$=2^{k}$; $f_{o}$ denotes flexure produced by a horizontal force equal to the weight of pendulum ($6^{k}.308$).

### 1879, February 18.

Scale $\frac{3}{4}$-inch ($=2^{cm}$) above, and 12.5 inches ($=32^{cm}$) forward of middle of knife-edge; 22.4 div. of scale$=100^{\mu}$. C. S. P., observer.

*Scale readings.*

| Wt. off. | Wt. on. | Diff. | $f_{o}$ |
|---|---|---|---|
| .... | .... | 1.2 | $\mu$ |
| .... | .... | 1.2 | 15.1 |
| .... | .... | 1.1 | |
| | | div.<br>1.17 | |

The following measures were made under a higher power of microscope; 58 div. of scale$=100^{\mu}$.

| | | | | |
|---|---|---|---|---|
| | 37.0<br>36.7 | 34.0 | 2.85 | 16 |
| | 35.7<br>36.0 | 33.1<br>33.4 | 2.6 | 15 |
| | 37.7<br>37.9<br>38.0<br>38.6 | 35.0<br>35.0<br>35.2 | 3.0 | 16 |
| Mean, | | | | 16 |

In the following measures, 37 div. of scale$=100^{\mu}$; otherwise same as preceding.

| | | | |
|---|---|---|---|
| 24.1 | 22.2 | 1.9 | $16^{\mu}$ 4 |

### 1879, FEBRUARY 20.

Scale ½ inch (=$1^{cm}$) above, and 12½ inches (=$32^{cm}$) behind middle of knife-edge; 23.5 div. of scale=$100^{\mu}$.

*Scale readings.*

| Wt. off. | Wt. on. | Diff.<br>div. | $f_0$.<br>$\mu$ |
|---|---|---|---|
| 6.3 | 11.4 | | |
| 6.5 | 11.2 | 4.7 | 63 |
| 6.6 | 11.2 | | |
| 7.0 | | | |

In the following, 28.3 div. of scale=$100^{\mu}$; otherwise the same.

| Wt. off. | Wt. on. | Diff. | $f_0$. |
|---|---|---|---|
| 35.4 | 40.5 | | |
| 35.6 | 40.4 | 4.8 | 54 |
| 35.7 | 40.4 | | |
| 35.7 | | | |
| 63.4 | 68.4 | | |
| 63.6 | 68.9 | 5.0 | 56 |
| 64.0 | 68.9 | | |
| 64.0 | | | |
| Mean, | | | 55 |

In the following, 41.1 div. of scale=$100^{\mu}$; otherwise same.

| Wt. off. | Wt. on. | Diff. | $f_0$. |
|---|---|---|---|
| 20.8 | 25.0 | 4.4 *rej.* | |
| 30.5 | 35.0 | | |
| 71.5 | 78.0 | | |
| 71.6 | 78.1 | 6.5 | 64 |
| 71.6 | 78.0 | | |
| 71.4 | 78.8 | | |

### 1879, MARCH 4.

Scale 1 inch (=$2^{cm}.5$) above, and 13½ inches ($34^{cm}.5$) behind middle of knife-edge; 26.7 div. of scale=$100^{\mu}$. H. Farquhar, observer.

| | | | |
|---|---|---|---|
| .... | .... | 5.4 | 64 |

Scale next put $2^{cm}$ above and 14 inches (=$35^{cm}$) forward of middle of knife-edge; 26.7 div. of scale=$100^{\mu}$.

| | | | |
|---|---|---|---|
| .... | .... | 1.0 | 12 |

### 1879, MARCH 6.

Scale on level of knife-edge and 15 inches (=$38^{cm}$) forward; 38.5 div. of scale=$100^{\mu}$.

| | | | |
|---|---|---|---|
| .... | .... | 1.9 | 16 |

Scale next put 55 inches (=$140^{cm}$) below middle of knife-edge; 33.3 div. of scale=$200^{\mu}$.

| | | | |
|---|---|---|---|
| .... | .... | 1.6 | 302 |

The following is a summary of the above. $F_0$ here and elsewhere denotes the flexure at the middle of the knife-edge under a horizontal force equal to the weight of the pendulum. A=distance from middle point of knife-edge to its intersection with axis; B=distance from middle point of knife-edge to the intersection of axis with vertical line.

*C. S. P.'s observations.*

¾ inch above, $32^{cm}$ forward of knife-edge, $f_0=16.1$
½ inch above, $32^{cm}$ behind, $f_0=55^{\mu}.7$
∴ Flexure at $2^{cm}$ above$=35^{\mu}.9$
$A=58^{cm}$.

*H. F.'s observations.*

$2^{cm}.0$ above, $35^{cm}$ forward of knife-edge, $f_0=12^{\mu}$
$2^{cm}.5$ above, $34^{cm}.5$ behind, $f_0=64^{\mu}$
∴ Flexure at $2^{cm}$ above$=38^{\mu}.18$
$A=51^{cm}$.
$140^{cm}$ directly below middle of knife-edge, $f_0=156$.
∴ $F_0=40^{\mu}.66$; A (mean)$=54^{cm}$,
$B=29^{cm}$.

### EBENSBURG.

At this station the Repsold tripod stood on a hard floor of clay. Statical flexure measured by means of weight of $1.0818^{k}$. C. S. P., observer.

1879, SEPTEMBER 26.

The two screw-taps binding the front legs of the tripod to top of the stand were first tightened *by hand.* Scale on the level of the point of suspension, $50^{cm}$ to the right, and $18^{cm}.4$ forward of middle of knife-edge. 21.6 div. of scale=.001 inch.

*Scale readings.*

| Wt. off. | Wt. on. | Mean diff. | $f_0$.<br>μ |
|---|---|---|---|
| 8. 4 | 61. 3 | | |
| 9. 4 | 61. 3 | 52. 3 | 358 |
| 9. 6 | 61. 6 | | |

P. M.—Taps wrench-tightened; scale $18^{cm}.4$ *directly* forward of knife-edge; 20.7 div. of scale=.001 inch.

| | | | |
|---|---|---|---|
| 35. 0 | 82. 3 | 47. 2 | 337 |
| 35. 0 | 81. 8 | | |
| 34. 5 | 82. 0 | | |
| 34. 6 | 81. 6 | | |

Taps next loosened.

| | | | |
|---|---|---|---|
| 25. 5 | 82. 0 | 54. 7 | 391 |
| 28. 0 | 82. 3 | | |
| 28. 3 | 82. 1 | | |
| 28. 3 | 82. 5 | | |

Taps next hand-tightened.

| | | | |
|---|---|---|---|
| 16. 0 | 67. 6 | 51. 5 | 368 |
| 16. 0 | 67. 5 | | |
| 16. 2 | 67. 6 | | |
| 16. 0 | 67. 7 | | |
| 16. 7 | | | |

### 1879, SEPTEMBER 27.

Scale $18^{cm}.4$ forward of middle of knife-edge, as before; 21.8 div. of scale=.001 inch. Taps tightened by Mr. F. about as tight as during last four days of pendulum swinging. (*Note.*—It had been discovered that during these days the taps had only been tightened by hand.)

*Scale readings.*

| Wt. off. | Wt. on. | Mean diff. | *fo.* μ |
|---|---|---|---|
| 19.0 | 47.8 rej. | | |
| 18.4 | 69.0 | 50.5 | 343 |
| 18.2 | 69.0 | | |

In the following measures, 21.6 div. of scale=.001 inch. Microscope refocussed.

| | | | | | |
|---|---|---|---|---|---|
| 21.0 | 71.5 | | | | |
| 20.9 | 71.5 | 50.4 | 346 | | |
| 21.0 | 71.0 | | | | |
| 20.5 | 71.0 | | | | |
| | | | | Position of lines of stage micrometer, read on eye-piece micrometer. | |
| 21.8 | 72.8 | | | 0.1 | 0.5 |
| 22.0 | 72.9 | 50.9 | 349 | 21.8 | 21.9 |
| 22.0 | 73.0 | | | 43.3 | 43.4 |
| 22.0 | | | | 64.7 | 64.9 |
| | | | | 86.5 | 86.8 |
| Mean interval | | | | 21.55 | 21.55 |

Screws now somewhat loosened by Mr. F.

| | | | | | |
|---|---|---|---|---|---|
| 2.5 | 55.5 | | | 13.2 | 12.5 |
| 2.5 | 55.5 | 53.0 | 363 | 34.7 | 34.5 |
| 2.3 | 55.4 | | | 77.7 | 77.4 |
| | | | | 99.5 | 99.1 |
| Mean interval | | | | 21.55 | 21.58 |

Screw-taps now tightened as tight as possible with fingers; 21.6 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 18.5 | 69.6 | | | 7.0 | 4.6 |
| 18.6 | 69.6 | 50.8 | 348 | 28.5 | 26.3 |
| 18.6 | 69.0 | | | 49.8 | 47.6 |
| | | | | 71.5 | 69.5 |
| | | | | 93.2 | 91.0 |
| Mean interval | | | | 21.53 | 21.6 |

Screw-taps now tightened with wrench by Mr. P.; 21.2 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 20.0 | 67.4 | | | 16.5 | 20.0 |
| 20.0 | 67.3 | 47.4 | 331 | 37.7 | 40.9 |
| 19.6 | 67.2 | | | 59.0 | 62.2 |
| | | | | 81.6 | 83.5 |
| Mean interval | | | | 21.25 | 21.2 |

New set. Screws entirely loose; 21.6 div. of scale=.001 inch.

| | | | | | | |
|---|---|---|---|---|---|---|
| 21.5 | 75.8 | | | 16.6 | 11.2 | 10.8 |
| 22.0 | 76.0 | 54.0 | 370 | 38.5 | 33.2 | 32.7 |
| 21.8 | 75.7 | | | 59.7 | 54.8 | 54.6 |
| 21.7 | | | | | 76.6 | 76.1 |
| | | | | 81.7 | 97.9 | 97.4 |
| Mean interval | | | | 21.58 | 21.68 | 21.67 |

Screws now tightened by hand of Mr. F. "about right"; 21.6 div. of scale=.001 inch.

*Scale readings.*

| Wt. on. | Wt. off. | Mean diff. | $f_0$. | Position of lines of stage micrometer, read on eye-piece micrometer. | |
|---|---|---|---|---|---|
| 17.0 | 67.6 | | μ | 3.4 | 1.8 |
| 17.1 | 67.3 | 50.2 | 344 | 24.9 | 24.0 |
| 17.0 | 67.0 | | | 46.4 | 45.3 |
| 17.2 | | | | 68.1 | 67.2 |
| | | | | 89.5 | 88.6 |
| Mean interval .................. | | | | 21.55 | 21.66 |

Screws again hand tightened "about right"; scale as above.

| | | | | | |
|---|---|---|---|---|---|
| 20.4 | 70.0 | | | 8.5 | 5.0 |
| 20.4 | 70.0 | 49.8 | 341 | 30.6 | 26.8 |
| 20.0 | 69.9 | | | 57.8 | 48.5 |
| 20.1 | | | | 73.3 | 69.9 |
| | | | | 94.9 | 91.4 |
| Mean interval .................. | | | | 21.52 | 21.58 |

Screws again tightened by hand "about right"; 21.5 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 11.5 | 61.5 | | | 0.7 | |
| 11.4 | 61.2 | 50.0 | 344 | 22.9 | |
| 11.2 | | | | 43.9 | |
| | | | | 65.7 | |
| | | | | 87.0 | |
| Mean interval .................. | | | | 21.52 | |

The last set of measures were not regarded as being so satisfactory as the preceding.

Head of stand taken off, put on again, and tightened with wrench. Scale 18$^{cm}$.6 forward of middle of knife-edge; 21.4 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 36.4 | 83.4 | | | 2.6 | 7.9 |
| 36.4 | 83.1 | 46.8 | 324 | 13.4 | 18.7 |
| 36.4 | 83.1 | | | 23.0 | 29.2 |
| 36.4 | | | | 34.5 | 40.0 |
| | | | | 45.5 | 50.8 |
| | | | | 56.1 | 61.6 |
| | | | | 66.9 | 72.1 |
| | | | | 77.4 | 82.6 |
| | | | | 87.8 | |
| Mean interval .................. | | | | 21.47 | 21.41 |

Another set; 21.4 div. of scale=.001 inch. *N. B.*—In this and following sets the positions of several, generally three, lines of the stage micrometer are read off on the eye-piece micrometer, between all the changes of the weight. This explains the separation of the numbers in the first two columns into groups.

| | | | | | |
|---|---|---|---|---|---|
| 37.4 | 84.2 | | | 4.0 | 5.3 |
| 32.3 | 79.4 | | | 13.5 | 10.7 |
| 26.6 | 74.1 | 47.1 | 327 | 24.3 | 16.0 |
| | | | | 35.0 | 21.3 |
| 36.9 | 84.2 | | | 46.2 | 26.4 |
| 31.8 | 79.3 | | | 56.6 | 31.9 |
| 26.4 | 74.1 | 47.5 | | 67.7 | 36.9 |
| | | | | 78.0 | |
| | | | | 88.8 | |
| Mean interval .................. | | | | 21.43 | 21.07 |

Another set; 21.5 div. of scale=.001 inch.

| Wt. on. | Wt. off. | Mean diff. | $f_0$. | Position of lines of stage micrometer, read on eye-piece micrometer. | |
|---|---|---|---|---|---|
| 28.3 | 74.5 | | | 32.1 | 31.1 |
| 33.2 | 80.0 | 46.6 | | 37.9 | 37.1 |
| 38.4 | 85.3 | | | 43.3 | 42.3 |
| | | | | 47.9 | 47.0 |
| 27.6 | 74.5 | | | 54.0 | 53.0 |
| 33.0 | 80.0 | 47.0 | | 59.2 | 58.6 |
| 38.2 | 85.3 | | | 64.8 | 63.9 |
| | | | | 70.0 | 68.9 |
| 27.6 | 74.6 | | | 75.1 | 74.5 |
| 33.0 | 80.0 | | μ | 80.8 | 79.8 |
| 38.2 | 84.9 | 46.9 | 323 | 85.8 | 85.0 |
| | | | | —— | —— |
| 28.0 | 74.6 | | Mean interval. | 21.51 | 22.55 |
| 32.9 | 80.0 | | | | |
| 38.0 | 84.9 | 46.9 | | | |
| 28.0 | 75.1 | | | | |
| 32.9 | 79.9 | | | | |
| 38.0 | 85.1 | 47.1 | | | |
| 27.8 | 74.1 | | | | |
| 33.0 | 79.9 | | | | |
| 38.0 | 85.1 | 46.8 | | | |

Stand reversed. Scale $42^{cm}.5$ behind middle of knife-edge; 21.6 div. of scale=.001 inch.

*Scale readings.*

| Wt. off. | Wt. on. | Mean diff. | $f_0$. | Lines of scale. | | |
|---|---|---|---|---|---|---|
| 3.0 | 28.8 | | | 5.0 | 18.4 | 6.6 |
| 24.4 | 50.6 | 26.0 | | 26.8 | 39.5 | 27.5 |
| | | | μ | 37.2 | 61.5 | 48.8 |
| 3.7 | 29.1 | | 177 | 47.9 | 83.0 | 70.6 |
| 25.0 | 50.9 | 25.6 | | | | 92.6 |
| 46.5 | 72.0 | | | —— | —— | —— |
| | | | Mean interval. | 21.6 | 21.6 | 21.5 |

Microscope refocussed. Scale 21.6 div.=.001 inch.

| | | | | |
|---|---|---|---|---|
| 5.6 | 31.0 | 25.7 | | 13.0 |
| 26.7 | 52.7 | | | 34.0 |
| | | | | 56.0 |
| 7.4 | 32.4 | | 176 | 77.2 |
| 28.4 | 54.0 | 25.7 | | —— |
| 48.8 | 75.4 | | Mean interval. | 21.55 |

Again, 21.4 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 12.5 | 38.6 | | | 17.0 | 18.6 |
| 33.4 | 60.2 | | | 38.6 | 40.2 |
| 54.0 | 81.4 | | | 60.0 | 61.6 |
| | | | | 81.5 | 82.9 |
| 14.0 | 39.5 | 26.8 | 181 rej. | —— | —— |
| 35.0 | 61.2 | | Mean interval. | 21.47 | 21.4 |
| 56.0 | 82.5 | 26.1 | | | |
| 14.4 | 39.5 | | | | |
| 35.6 | 61.2 | | | | |
| 56.5 | 82.5 | 25.6 | | | |

Screws next entirely loose; 21.5 div. of scale=.001 inch

*Scale readings.*

| Wt. on. | Wt. off. | Mean diff. | $f_0$. | Lines of scale. |
|---|---|---|---|---|
| 52.0 | 68.6 | | | 5.0 |
| 62.7 | 79.6 | | μ | 16.1 |
| 73.2 | 90.4 | 16.9 | 115 | 28.8 |
| | | | | 37.5 |
| 52.5 | 68.4 | | | 48.0 |
| 62.9 | 79.3 | | | 59.1 |
| 73.2 | 90.0 | 16.4 | | 69.6 |
| | | | | 80.6 |
| | | | | 91.1 |
| | | | | 21.5 |

Screws now hand-tightened "about right," by H. F.; 21.6 div. of scale=.001 inch.

| | | | | |
|---|---|---|---|---|
| 1.5 | 21.3 | | | 6.0 |
| 1.3 | 21.4 | 20.0 | 137 | 92.2 |
| 1.2 | | | | |
| | | | | 21.55 |

Again, 21.6 div. of scale=.001 inch.

| | | | | |
|---|---|---|---|---|
| 8.7 | 29.0 | | | 18.6 |
| 8.5 | 28.9 | 20.2 | 138 | 94.2 |
| 9.0 | 28.8 | | | |
| | | | | 21.6 |

Three bricks were next put on the bottom of the stand; weight, 4 pounds $5\frac{1}{2}$ ounces, 4 pounds $6\frac{3}{4}$ ounces, 4 pounds $11\frac{1}{2}$ ounces, respectively. The following measures were taken at $41^{\text{cm}}.4$ behind the middle of knife-edge, and $0^{\text{cm}}.7$ above level of support. Screws hand-tightened, as in last observations; 21.4 div. of scale=.001 inch.

| | | | | |
|---|---|---|---|---|
| 16.5 | 34.4 | 17.9 | 124 | 2.2 |
| 16.5 | | | | 87.8 |
| | | | | 21.4 |

Refocussed. Scale as above.

| | | | | |
|---|---|---|---|---|
| 20.2 | 38.5 | 18.4 | 127 | 9.5 |
| 20.2 | 38.6 | | | 73.7 |
| | | | | 21.4 |

Screws next tightened with wrench; 21.7 div. of scale=.001 inch. Measures taken $1^{\text{cm}}.4$ above level of support.

| | | | | | |
|---|---|---|---|---|---|
| 67.3 | 93.0 | | | 2.4 | 5.6 |
| 67.4 | 92.4 | | | 88.8 | 92.7 |
| 67.3 | 92.6 | 25.2 | 172 | | |
| 67.8 | 92.7 | | | 21.6 | 21.7 |

Measure taken $4^{\text{cm}}.1$ below level of support; 21.6 div. of scale=.001 inch. Stage micrometer fixed to the top of the tripod, but not to the tongue on which the pendulum rests.

| | | | | |
|---|---|---|---|---|
| 10.8 | 41.0 | | | 18.6 |
| 12.2 | 40.6 | 29.3 | 201 | 83.5 |
| 13.6 | 42.8 | | | |
| | | | | 21.6 |

Again, 21.7 div. of scale=.001 inch.

| | | | | |
|---|---|---|---|---|
| 16.0 | 45.0 | | | 11.8 |
| 16.9 | 46.0 | 29.0 | 197 | 98.5 |
| 18.0 | 46.8 | | | |
| | | | | 21.7 |

Again, 21.6 div. of scale=.001 inch.

| Wt. off. | Wt. on. | Mean diff. | $f_0$. | Lines of scale. |
|---|---|---|---|---|
| *Scale readings.* | | | | |
| | | | μ | |
| 20. 7 | 50. 0 | 29. 2 | 201 | 7. 0 |
| 21. 0 | 50. 2 | | | 93. 4 |
| | | | | 21. 6 |

Again, scale 21.5 div.=.001 inch.

| | | | | |
|---|---|---|---|---|
| 23. 0 | 51. 7 | 29. 1 | 200 | 22. 2 |
| | 52. 5 | | | 86. 8 |
| | | | | 21. 5 |

The bricks were now removed from base of support, and pendulum suspended heavy end down; 21.4 div. of scale=.001 inch. Screws wrench-tightened.

| | | | | |
|---|---|---|---|---|
| 8. 0 | 37. 4 | 29. 2 | 202 | 16. 0 |
| 8. 5 | 37. 5 | | | 80. 3 |
| | | | | 21. 4 |

Again, 21.6 div. of scale=.001 inch. "Good."

| | | | | |
|---|---|---|---|---|
| 7. 5 | 37. 5 | | | 7. 9 |
| 7. 5 | 36. 8 | 29. 9 | 206 | 94. 3 |
| | 38. 0 | | | |
| | | | | 21. 6 |

The following is a summary of the observations with weight and pulley at Ebensburg, on Repsold stand. $F_0$=flexure at middle point of knife edge, under a horizontal force equal to the weight of the pendulum; A=distance from middle point of knife-edge to intersection of axis with knife-edge.

| Arrangement. | $f_0$. $18^{cm}.4$ forward, $0^{cm}.7$ above. | $f_0$. $42^{cm}.5$ back, $0^{cm}.7$ above. | $f_0$. $10^{cm}$ from axis of rotation. | A. | $F_0$. |
|---|---|---|---|---|---|
| | μ | μ | μ | *Cm.* | μ |
| Front taps wrenched up | 337 | 177 | | | |
| | 331 | 176 | | | |
| | 324 | ............ | | | |
| | 327 | ............ | | | |
| | 323 | ............ | | | |
| | 328 | 176. 5 | 24. 9 | 113. 5 | 283 |
| Front taps hand-tightened | 343 | 137 | | | |
| | 349 | 138 | | | |
| | 344 | ............ | | | |
| | 341 | ............ | | | |
| | 344 | ............ | | | |
| | 342 | 137. 5 | 33. 6 | 83. 4 | 281 |
| Taps somewhat loose | 363 | ............ | ............ | ............ | ............ |
| Front taps loose | 391 | 115 | 45. 3 | 67. 9 | 309 |
| | | $41^{cm}.4$ back. | Calculated from above without bricks. | | |
| | | μ | μ | | |
| Tripod loaded with bricks; taps hand-tightened | ............ | 124 | | | |
| | | 127 | | | |
| | | 125. 5 | 141 | | |
| Taps wrenched | ............ | 172 | 179 | | |
| | | *With bricks.* | *W'thout bricks.* | | |
| Flexure of tripod without that of tongue; taps wrenched | ............ | 201 | 202 | | |
| | | 197 | 206 | | |
| | | 201 | ............ | | |
| | | 200 | ............ | | |
| | | 200 | 204 | | |

It will be seen that the effect of loosening the front taps is to increase the angular flexure about the instantaneous axis. But this axis is at the same time brought forward, and the consequence is that the flexure at the middle point of the knife-edge is not much changed. That the flexure of the tripod alone, without that of the tongue supporting the pendulum, appears, when measured, $40^{cm}$ behind the middle point, to be greater than the combined flexure of the two, is no doubt due to the axis of flexure of the tongue cutting the level of the knife-edge only a short distance behind the middle point. The effect of loading the base of the tripod with bricks was to make it slightly stiffer when wrench-tightened, and considerably stiffer when hand-tightened. All of these measures of flexure seem, however, to be in error, and it seems likely that the position of the scale, when in front of the stand, was not really $184^{mm}$ as recorded, but perhaps $584^{mm}$. With that change, these measures would agree with others, which they do not now do.

The following are dynamical measurements. The pendulum swung heavy end down; 21.4 div. of scale=.001 inch. Arc expressed in ten-thousandths of the radius. Screws wrench-tightened; scale $41^{cm}.4$ behind, $0^{cm}.7$ above knife-edge.

1879, SEPTEMBER 27.

| Arc. | Scale readings. | | Diff. | $f_0$.<br>$\mu$ |
|---|---|---|---|---|
| 292 | 7.6 | 13.7 | 6.1 | 178 |
| 291 | 9.0 | 14.8 | 5.8 | 169 |
| 290 | 6.7 | 12.8 | 6.1 | 179 |

Another swing.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| 381 | 6.6 | 14.7 | 8.1 | 179 |
| 379 | 7.8 | 16.0 | 8.2 | 183 |
| 377 | 6.6 | 13.8 | 7.2 | 162 |
| 373 | 6.9 | 14.4 | 7.5 | 171 |
| 370 | 0.0 | 7.8 | 7.8 | 179 |
| | Mean | | | 175.0 |

1879, SEPTEMBER 28.

Scale 1.0 to 87.6=.004 inch. Other conditions same as before.

| Arc. | Scale readings. | | Diff. | $f_0$.<br>$\mu$ |
|---|---|---|---|---|
| 520 | 5.0 | 15.9 | 10.9 | 175 |
| 512 | 4.0 | 14.8 | 10.8 | 178 |
| 506 | 0.0 | 10.7 | 10.7 | 178 |
| 503 | 0.5 | 11.3 | 10.8 | 181 |
| 496 | 7.7 | 17.8 | 10.1 | 170 |
| 492 | 3.8 | 14.3 | 10.5 | 177 |
| 487 | 2.3 | 12.0 | 9.7 | 166 |
| 479 | 2.6 | 12.8 | 10.2 | 177 |
| 465 | 8.7 | 17.8 | 9.1 | 163 |
| 459 | 5.1 | 14.8 | 9.7 | 178 |
| 455 | 2.2 | 11.4 | 9.2 | 168 |
| 290 | 3.9 | 10.0 | 6.1 | 175 |
| | Mean | | | 173.8 |

Stopped, and started again.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| 392 | 3.6 | 11.7 | 8.1 | 173 |
| 383 | 0.3 | 8.2 | 7.9 | 173 |
| | Mean | | | 173.0 |

The following are statical measures of the flexure produced by drawing the pendulum to one side over a meaured arc; steel tongue used instead of wooden strip before employed. Scale $44^{cm}.4$ behind middle of knife-edge, and $2^{cm}.5$ below its level; 1.0 to 87.6 div. of scale=.004 inch.

| | Scale readings; pend. vertical. | | Scale readings; pend. inclined. | | Arc. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|---|---|
| | | | | | | | $\mu$ |
| | 9.7 | 74.5 | 16.6 | 81.1 | 474 | 6.75 | 233 |
| | 10.4 | 74.8 | 16.0 | 80.9 | 465 | 5.85 | 207 |
| Again. | | | | | | | |
| | 10.7 | 75.3 | 16.9 | 81.6 | 474 | 6.25 | 217 |
| | 11.3 | 76.3 | 16.1 | 80.7 | 475 | 4.60 | 159 |
| | 11.6 | 76.5 | 15.8 | 80.4 | 438 | 4.05 | 151 |
| | 10.8 | 75.6 | 16.1 | 80.8 | 486 | 5.25 | 177 |
| | 11.1 | 76.0 | 16.2 | 80.7 | 489 | 4.90 | 164 |
| | 10.8 | 75.8 | 16.2 | 80.1 | 429 | 4.85 | 186 |
| | 9.6 | 74.3 | 15.9 | 80.8 | 450 | 6.40 | 233 |
| | 7.3 | 71.9 | 12.9 | 77.7 | 501 | 5.70 | 187 |
| | 9.5 | 74.5 | 15.0 | 79.7 | 500 | 5.35 | 175 |
| | 10.1 | 74.8 | 16.0 | 80.6 | 515 | 5.85 | 187 |
| | 9.6 | 74.2 | 15.0 | 79.7 | 490 | 5.45 | 182 |
| | | | | | | | 189 |

Dynamical measurements; 21.6 div. of scale=.001 inch.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | $\mu$ |
| 496 | 8.8 | 19.7 | 10.9 | 185 |
| 493 | 1.6 | 11.3 | 9.7 | 166 |
| 490 | 12.3 | 22.6 | 10.3 | 177 |
| 488 | 13.6 | 23.9 | 10.3 | 178 |
| 485 | 8.7 | 19.4 | 10.7 | 186 |
| 482 | 0.9 | 11.0 | 10.1 | 177 |
| 480 | 12.6 | 22.7 | 10.1 | 177 |
| 477 | 13.7 | 23.8 | 10.1 | 179 |
| 474 | 9.0 | 19.3 | 10.3 | 182 |
| 472 | 0.9 | 10.8 | 9.9 | 177 |
| 469 | 12.5 | 22.7 | 10.2 | 183 |
| 466 | 13.8 | 23.7 | 9.9 | 179 |
| 463 | 3.8 | 13.7 | 9.9 | 180 |
| 460 | 0.7 | 10.6 | 9.9 | 181 |
| 458 | 2.4 | 11.9 | 9.5 | 174 |
| 455 | 3.5 | 13.3 | 9.8 | 181 |
| | | | | 178.8 |

Tongue readjusted. Scale $44^{cm}.6$ behind middle of knife-edge, and same height as before. Screws hand-tightened by H. F.; 3.3 to 89.2 div. of scale=.004 inch.

| | | | | |
|---|---|---|---|---|
| | | | | $\mu$ |
| 466 | 10.6 | 18.9 | 8.3 | 150 |
| 463 | 11.6 | 19.9 | 8.3 | 150 |
| 461 | 3.6 | 12.2 | 8.6 | 157 |
| 460 | 5.4 | 13.7 | 8.3 | 151 |
| 457 | 0.4 | 8.8 | 8.4 | 155 |
| 450 | 1.7 | 9.9 | 8.2 | 154 |
| 447 | 4.9 | 13.3 | 8.4 | 158 |
| 445 | 5.7 | 13.9 | 8.2 | 155 |
| | | | | 153.8 |

Statical flexure with same arrangement.

| Scale readings; pend. vertical. | | Scale readings; pend. inclined. | | Arc. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|---|
| | | | | | | μ |
| 2.3 | 89.6 | 8.2 | 94.3 | 464 | 4.80 | 174 |
| 3.6 | 89.8 | 7.8 | 93.9 | 471 | 4.15 | 149 |
| 2.3 | 88.6 | 7.9 | 94.1 | 482 | 5.55 | 195 |
| 2.5 | 88.2 | 5.9 | 93.2 | 475 | 4.70 | 167 |
| 2.3 | 88.4 | 6.9 | 93.0 | 488 | 4.60 | 159 |
| 0.8 | 87.8 | 6.1 | 91.9 | 494 | 4.20 | 144 |
| 1.4 | 87.6 | 6.2 | 92.0 | 488 | 4.60 | 159 |
| | | | | | | 158.7 |

Screws now loosened, and again tightened by hand.

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | μ |
| 4.6 | 78.9 | 8.8 | 83.4 | 482 | 4.35 | 151 |
| 4.6 | 79.0 | 9.4 | 83.8 | 507 | 4.80 | 160 |
| 4.6 | 79.1 | 8.9 | 83.5 | 473 | 4.35 | 155 |
| 4.7 | 79.2 | 8.9 | 83.8 | 482 | 4.45 | 155 |
| | | | | | | 155.3 |

Dynamical measures with last arrangement; 21.3 div. of scale=.001 inch.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| 512 | 0.3 | 9.4 | 9.1 | 151 |
| 508 | 1.3 | 10.5 | 9.2 | 154 |
| 506 | 1.6 | 10.8 | 9.2 | 155 |
| 504 | 2.7 | 11.7 | 9.0 | 152 |
| 503 | 3.7 | 12.4 | 8.7 | 147 |
| 500 | 4.8 | 13.6 | 8.8 | 150 |
| 498 | 0.2 | 8.9 | 8.7 | 149 |
| 496 | 1.1 | 9.8 | 8.8 | 150 |
| 495 | 1.8 | 10.7 | 8.9 | 153 |
| | | | | 151.2 |

Screws retightened by H. F.

| | | | | |
|---|---|---|---|---|
| | | | | μ |
| 520 | 5.6 | 15.3 | 9.7 | 159 |
| 516 | 1.7 | 16.3 | 9.6 | 158 |
| 513 | 8.7 | 13.1 | 9.4 | 156 |
| 512 | 0.4 | 9.7 | 9.3 | 155 |
| 509 | 6.0 | 15.7 | 9.7 | 162 |
| 507 | 7.3 | 16.6 | 9.3 | 156 |
| 504 | 9.0 | 18.4 | 9.4 | 159 |
| 501 | 0.7 | 9.9 | 9.2 | 156 |
| | | | | 157.6 |

Statical flexure. Same arrangement; 21.6 div. of scale=.001 inch.

| Pend. vertical. | | Pend. inclined. | | Arc. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|---|
| | | | | | | μ |
| 18.6 | 83.3 | 23.1 | 87.7 | 464 | 4.45 | 162 |
| 19.6 | 83.5 | 23.4 | 88.1 | 514 | 4.70 | 153 |
| 18.6 | 83.5 | 23.3 | 87.8 | 488 | 4.50 | 155 |
| 18.4 | 83.4 | 23.3 | 87.9 | 467 | 4.70 | 170 |
| 18.6 | 83.5 | 23.6 | 88.3 | 513 | 4.90 | 162 |
| | | | | | | 160.4 |

Focussed. Same arrangement.

| Pend. vertical. | | Pend. inclined. | | Arc. | Mean diff. | $f_0$.<br>μ |
|---|---|---|---|---|---|---|
| 20.0 | 84.7 | 24.4 | 89.3 | 483 | 4.50 | 157 |
| 20.1 | 84.8 | 24.9 | 89.3 | 504 | 4.65 | 155 |
| 20.6 | 85.1 | 25.1 | 89.2 | 506 | 4.30 | 143 |
| 21.1 | 85.6 | 25.1 | 88.9 | 509 | .... | ... |
| 20.6 | 85.4 | 25.5 | 89.9 | 478 | 4.70 | 165 |
| | | | | | | 155. |

The stand turned around; tongue now projects in front of middle of knife-edge $33^{cm}.9$; height approximately as before; nuts wrenched up; dynamical.

| Arc. | Scale readings. | | Diff. | $f_0$.<br>μ |
|---|---|---|---|---|
| 472 | 7.3 | 23.4 | 16.1 | 287 |
| 470 | 5.6 | 21.3 | 15.7 | 281 |
| 467 | 4.0 | 20.3 | 16.3 | 293 |
| 465 | 7.6 | 22.9 | 15.3 | 277 |
| 462 | 5.7 | 20.9 | 15.2 | 277 |
| 460 | 7.7 | 22.9 | 15.2 | 278 |
| 457 | 5.8 | 21.0 | 15.2 | 280 |
| | | | | 281.9 |

Statical flexure. Same arrangement; 21.4 div. of scale=.001 inch.

| Scale readings; pend. vertical. | | Scale readings; pend. inclined. | | Arc. | Mean diff. | $f_0$.<br>μ |
|---|---|---|---|---|---|---|
| 5.7 | 80.2 | 13.0 | 87.1 | 398 | 7.20 | 307 |
| 15.4 | 79.6 | 23.8 | 88.1 | 460 | 8.45 | 312 |
| 15.4 | 79.7 | 23.7 | 87.9 | 476 | 8.25 | 294 |
| 15.4 | 79.6 | 23.7 | 87.7 | 485 | 8.20 | 287 |
| 14.8 | 79.3 | 23.6 | 87.9 | 496 | 8.70 | 297 |
| 14.9 | 79.3 | 23.7 | 88.0 | 480 | 8.75 | 309 |
| 14.6 | 79.1 | 23.4 | 87.6 | 488 | 8.65 | 300 |
| 14.7 | 79.2 | 23.5 | 87.5 | 491 | 8.55 | 353 |
| 14.7 | 78.9 | 23.5 | 87.6 | 500 | 8.75 | 297 |
| 14.6 | 78.7 | 23.5 | 87.7 | 504 | 8.95 | 302 |
| | | | | | | 300.5 |

Dynamical flexure; 21.4 div. of scale=.001 inch; nuts tightened by hand of H. F.

| Arc. | Scale readings. | | Diff. | $f_0$.<br>μ |
|---|---|---|---|---|
| 426 | 6.1 | 22.6 | 16.5 | 328 |
| 422 | 2.2 | 18.6 | 16.4 | 330 |
| 420 | 6.3 | 22.6 | 16.3 | 329 |
| 417 | 4.7 | 21.2 | 16.5 | 336 |
| 414 | 5.5 | 21.7 | 16.2 | 332 |
| 412 | 3.8 | 19.8 | 16.0 | 329 |
| 410 | 6.3 | 22.2 | 15.9 | 329 |
| | | | | 330.4 |

Statical flexure; last arrangement.

| Scale readings; pend. vertical. | | Scale readings; pend. inclined. | | Arc. | Mean diff. | $f_0$. $\mu$ |
|---|---|---|---|---|---|---|
| 13.9 | 78.3 | 23.9 | 87.8 | 490 | 9.75 | 340 |
| 14.0 | 78.1 | 24.1 | 88.3 | 502 | 10.15 | 345 |
| 14.1 | 78.3 | 24.3 | 88.4 | 511 | 10.15 | 338 |
| 14.5 | 78.5 | 24.4 | 88.4 | 503 | 9.90 | 334 |
| 14.5 | 78.4 | 24.0 | 87.9 | 480 | 9.50 | 336 |
| 14.5 | 78.6 | 24.8 | 88.7 | 521 | 10.20 | 333 |
| 14.2 | 78.2 | 23.5 | 87.7 | 476 | 10.40 | 370 |
| 14.0 | 78.4 | 23.6 | 87.7 | 485 | 9.45 | 331 |
| 14.0 | 77.9 | 23.9 | 87.9 | 504 | 9.45 | 319 |
| 14.5 | 78.6 | 23.9 | 88.0 | 490 | 9.40 | 326 |
| | | | | | | 333.6 |

Nuts readjusted by hand. Same arrangement as before.

| | | | | | | |
|---|---|---|---|---|---|---|
| 24.1 | 88.2 | 32.9 | 97.0 | 437 | 8.80 | 341 |
| 24.2 | 88.3 | 34.3 | 98.5 | 504 | 10.15 | 341 |
| 23.5 | 88.3 | 33.8 | 97.8 | 475 | 10.40 | 372 |
| 23.8 | 87.7 | 33.1 | 97.4 | 466 | 9.50 | 346 |
| 23.5 | 87.5 | 32.5 | 96.7 | 455 | 9.10 | 340 |
| 23.5 | 87.6 | 33.4 | 97.7 | 496 | 10.00 | 343 |
| 23.6 | 87.6 | 34.4 | 98.6 | 542 | 10.90 | 341 |
| 23.4 | 87.5 | 33.2 | 97.1 | 475 | 9.70 | 346 |
| 23.4 | 87.6 | 32.3 | 96.5 | 433 | 8.90 | 350 |
| 23.5 | 87.6 | 32.9 | 97.0 | 474 | 9.40 | 336 |
| | | | | | | 342.7 |

Dynamical flexure. Same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. $\mu$ |
|---|---|---|---|---|
| 384 | 0.7 | 15.7 | 15.0 | 331 |
| 382 | 6.6 | 21.7 | 15.1 | 334 |
| 380 | 8.3 | 23.0 | 14.7 | 329 |
| 379 | 10.3 | 24.7 | 14.4 | 322 |
| 484 | 8.5 | 27.7 | 19.2 | 336 |
| 479 | 6.1 | 24.7 | 18.6 | 329 |
| 474 | 6.6 | 24.8 | 18.2 | 326 |
| 471 | 8.2 | 26.6 | 18.4 | 331 |
| | | | | 329.8 |

Screws again tightened by hand of H. F.

| | | | | |
|---|---|---|---|---|
| 412 | 3.0 | 19.4 | 16.4 | 337 |
| 410 | 4.1 | 20.6 | 16.5 | 341 |
| 408 | 2.6 | 19.3 | 16.7 | 347 |
| 407 | 4.2 | 20.4 | 16.2 | 337 |
| 405 | 3.2 | 19.3 | 16.1 | 337 |
| 404 | 4.4 | 20.2 | 15.8 | 332 |
| 523 | 0.5 | 21.5 | 21.0 | 340 |
| 520 | 0.6 | 21.6 | 21.0 | 342 |
| 518 | 5.5 | 25.9 | 20.4 | 334 |
| 514 | 3.8 | 24.3 | 20.5 | 338 |
| 511 | 1.0 | 21.3 | 20.3 | 336 |
| 506 | 5.5 | 25.7 | 20.2 | 338 |
| 504 | 5.4 | 24.8 | 19.4 | 328 |
| | | | | 337.4 |

Statical flexure; same arrangement; 21.5 div. of scale=.001 inch.

| Scale readings; pend. vertical. | | Scale readings; pend. inclined. | | Arc. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|---|
| 10. 6 | 75. 4 | 20. 9 | 85. 1 | 492 | 10. 00 | 346 |
| 10. 9 | 75. 1 | 20. 1 | 84. 4 | 457 | 9. 25 | 344 |
| 10. 6 | 74. 9 | 20. 3 | 84. 7 | 485 | 9. 75 | 341 |
| 10. 4 | 74. 9 | 20. 8 | 82. 0 | 509 | 10. 25 | 342 |
| 10. 5 | 74. 9 | 21. 2 | 85. 9 | 505 | .... . | ... |
| 10. 6 | 75. 3 | 21. 0 | 84. 2 | 494 | .... . | ... |
| 10. 6 | 75. 3 | 21. 0 | 84. 8 | 501 | 9. 95 | 337 |
| 10. 4 | 75. 0 | 21. 3 | 85. 7 | 517 | 10. 80 | 355 |
| 10. 4 | 74. 6 | 20. 4 | 84. 9 | 496 | 10. 15 | 347 |
| 10. 3 | 74. 7 | 20. 5 | 84. 9 | 500 | 10. 20 | 346 |
| | | | | | $10^{div}. 03$ | 344. 7 |

Summary of observations with pendulum, dynamical and statical, made at Ebensburg on Repsold stand.

*Nuts wrenched.*

| | Dynam. | Stat. |
|---|---|---|
| $44^{cm}.4$ behind knife-edge, | $f_0=178^{\mu}.8$ | $189^{\mu}.0$ |
| $33^{cm}.9$ forward, | $f_0=281^{\mu}.9$ | $300^{\mu}.9$ |
| | $\therefore F_0=237^{\mu}.2$ | $252^{\mu}.7$ |
| | $A=182^{cm}.9$ | $176^{cm}.5$ |

*Nuts hand-tightened.*

| | | |
|---|---|---|
| $44^{cm}.6$ behind knife-edge, | $f_0=154^{\mu}.2$ | $158^{\mu}.6$ |
| $33^{cm}.9$ forward, | $f_0=332^{\mu}.4$ | $339^{\mu}.4$ |
| | $\therefore F_0=255^{\mu}.4$ | $261^{\mu}.3$ |
| | $A=112^{cm}.5$ | $113^{cm}.4$ |

## YORK.

H. F., observer. All observations at this station, made in two positions, carefully brought to the level of the knife-edge plane. Ebensburg weight=$1^{k}.0818$.

### 1879, NOVEMBER 8.

Scale $47^{cm}$ in front of middle agate; 76.2 div. of scale=.003 inch; Geneva support.

*Scale readings.*

| Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|
| 28. 5 | 37. 0 | | |
| 28. 0 | 40. 0 | | $\mu$ |
| 28. 0 | 38. 0 | 10. 3 | 58. 7 |
| 28. 0 | 38. 5 | | |
| 28. 5 | 39. 0 | | |
| 29. 0 | 39. 0 | | |
| | | | |
| 23. 5 | 34. 0 | | |
| 24. 0 | 35. 0 | | |
| 24. 0 | 35. 0 | 10. 6 | 60. 4 |
| 24. 0 | 34. 0 | | |

| | | | | | |
|---|---|---|---|---|---|
| 22.5 | 33.5 | 6.0 | 18.0 | | |
| 23.9 | 33.0 | 6.0 | 16.5 | | |
| 23.0 | | 6.5 | 17.0 | 10.6 | 60.4 |
| | | 7.0 | 18.0 | | |
| | | 7.0 | 17.5 | | |
| | | 7.5 | 18.0 | | |
| | | 7.5 | 18.0 | | |
| | | 8.0 | | | |

Scale put on 46$^{cm}$ *behind* middle of agate; 85.5 div. of scale=.003 inch. Measures not very good, on account of jarring of machinery.

*Scale readings.*

| Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|
| 31.0 | 49.5 | | |
| 31.0 | 49.5 | | |
| 30.5 | 49.0 | | |
| 30.0 | 48.0 | 18.4 | $\overset{\mu}{93.5}$ |
| 29.5 | 48.0 | | |
| 29.5 | 47.0 | | |
| 29.0 | 47.0 | | |
| 28.5 | | | |
| | | | |
| 13.5 | 32.5 | | |
| 12.0 | 31.5 | | |
| 13.0 | 31.5 | | |
| 14.0 | 32.0 | 18.7 | 95.0 |
| 14.0 | 32.5 | | |
| 14.0 | 33.0 | | |
| 14.0 | 32.0 | | |
| 12.5 | | | |

## 1879, November 9.

Sunday. Shops all still. Scale 46$^{cm}$.6 *behind* the middle of the knife-edge; 91.87 div. of scale=.003 inch.

*Scale readings.*

| 0.003 inch. | | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 91.8 | 91.8 | 29.5 | 11.2 | | |
| 92.0 | 91.7 | 29.7 | 11.1 | | |
| 92.1 | 92.0 | 29.9 | 12.1 | | |
| 92.1 | 91.9 | 31.3 | 13.0 | | |
| 92.1 | 91.8 | 30.9 | 13.0 | | |
| | 92.0 | 31.7 | 14.0 | 18.1 | $\overset{\mu}{85.4}$ |
| | | 32.7 | 14.2 | | |
| | | 33.3 | 14.9 | | |
| | | 32.9 | 15.1 | | |
| | | 33.8 | 16.1 | | |

Again. 93.47 div. of scale=.003 inch.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
| 93.9 | 41.7 | 22.8 | | |
| 93.5 | 41.9 | 22.7 | | μ |
| 93.3 | 41.7 | 22.9 | 18.85 | 87.4 |
| 93.4 | 41.2 | 22.5 | | |
| 93.3 | 41.5 | 22.9 | | |
| 93.4 | 41.8 | | | |

Again. 93.51 div. of scale=.003 inch.

| | | | | |
|---|---|---|---|---|
| 93.4 | 37.3 | 18.7 | | |
| 93.3 | 37.2 | 18.1 | | |
| 93.8 | 36.9 | 18.0 | | |
| 93.7 | 36.6 | 18.1 | 18.8 | 87.2 |
| 93.4 | 36.6 | 17.7 | | |
| 93.3 | 36.7 | 18.0 | | |
| 93.7 | 37.5 | 18.3 | | |
| | 36.9 | 18.1 | | |
| | 36.9 | | | |

Scale put on 46$^{cm}$.6 *in front* of middle of knife-edge; 70.63 div. of scale=.002 inch.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| .002 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
| 70.8 | 27.0 | 37.0 | | |
| 70.3 | 26.6 | 37.9 | | μ |
| 70.9 | 26.8 | 37.0 | 10.4 | 42.6 |
| 70.6 | 26.4 | 37.0 | | |
| 70.9 | 26.7 | 37.0 | | |
| 70.3 | —— | —— | | |
| | 27.8 | 38.2 | | |
| | 27.7 | 38.0 | | |
| | 27.9 | | | |

Again. 70.57 div. of scale=.002 inch.

| | | | | |
|---|---|---|---|---|
| 70.8 | 22.7 | 33.1 | | |
| 70.2 | 24.7 | 35.4 | | |
| 70.7 | 25.4 | 35.8 | | |
| 70.7 | 25.9 | 36.3 | | |
| 70.4 | 25.3 | 35.9 | | |
| 70.6 | 25.5 | 36.1 | 10.24 | 42.0 |
| | 26.0 | 36.2 | | |
| | 26.4 | 36.1 | | |
| | 26.2 | 36.5 | | |
| | 26.0 | 35.9 | | |
| | 25.8 | 36.8 | | |
| | 27.0 | 37.0 | | |
| | 27.5 | | | |

Again. Draw-tube shortened; 97.25 div. of scale=.004 inch.

| .004 inch. | | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 97.1 | 96.8 | 24.1 | 32.1 | | |
| 97.3 | 96.9 | 25.0 | 31.9 | | |
| 96.8 | 97.2 | 24.1 | 31.3 | | |
| 97.5 | 97.3 | 24.0 | 31.3 | 7.49 | 44.6 |
| 97.4 | 97.7 | 23.8 | 31.5 | | |
| 97.6 | 97.7 | 23.9 | 31.8 | | |
| 97.2 | 97.3 | 24.6 | 31.9 | | |
| 97.0 | | 24.2 | 31.7 | | |
| | | 23.9 | | | |

## 1879, November 13.

5.30 p. m., and machinery stopped. Scale put on $46^{cm}$,6 *in front* of agate; 98.38 div. of scale=.004 inch.

*Scale readings.*

| .004 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 98.3 | 2.6 | 10.0 | | |
| 98.3 | 3.4 | 9.2 | | |
| 98.5 | 2.8 | 9.0 | | |
| 98.2 | 2.2 | 8.8 | | |
| 99.0 | 3.1 | | | |
| 98.2 | —— | —— | | $\mu$ |
| 98.2 | 2.8 | 8.9 | 6.43 | 37.8 |
| 98.3 | 2.1 | 8.9 | | |
| | 2.0 | 8.6 | | |
| | 2.9 | 8.3 | | |
| | 2.8 | 9.0 | | |
| | 2.0 | 10.0 | | |
| | 3.1 | 9.1 | | |
| | 3.0 | | | |

Again. Draw-tube lengthened; 97.84 div. of scale=.003 inch.

| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 97.8 | 26.8 | 36.7 | | |
| 97.6 | 28.2 | 38.1 | | |
| 98.1 | 27.8 | 37.2 | | |
| 98.0 | 28.0 | 36.8 | | |
| 97.9 | 27.9 | 37.6 | 9.01 | 40.0 |
| 97.8 | 29.2 | 37.2 | | |
| 97.6 | 28.0 | 37.4 | | |
| 97.9 | 29.7 | 37.2 | | |
| | —— | —— | | |
| | 29.8 | 39.1 | | |
| | 28.3 | 37.7 | | |
| | | 36.8 | | |

Again.

| | | | |
|---|---|---|---|
| 17.4 | 26.2 | | |
| 18.1 | 27.7 | | |
| 19.0 | 27.2 | | |
| 18.4 | 27.0 | 8.65 | 38.4 |
| 18.1 | 26.9 | | |
| 17.8 | 26.6 | | |
| 17.8 | 25.9 | | |
| 17.9 | | | |

## 1879, November 16.

Morning. Draw-tube=1.35; 82.28 div. of scale=.003 inch.

*Scale readings.*

| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 82.0 | 4.0 | 10.0 | | |
| 82.8 | 4.3 | 10.5 | | |
| 82.2 | 4.5 | 10.2 | | |
| 82.1 | 4.8 | 9.9 | | |
| 82.0 | 4.1 | 9.8 | 5.93 | 31.3 |

|  | *Scale readings.* |  |  |  |
|---|---|---|---|---|
| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
| 82.0 | 4.6 | 10.4 |  |  |
| 82.5 | 4.1 | 10.2 |  |  |
| 82.5 | 4.3 | 10.9 |  |  |
| 82.4 | 4.1 | 10.9 |  |  |
|  | 5.2 |  |  |  |

Draw-tube lengthened to 5.5; 76.14 div. of scale=.002 inch.

| .002 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 75.8 | 10.9 | 19.8 |  |  |
| 76.5 | 11.0 | 20.2 |  |  |
| 76.3 | 11.1 | 20.3 |  |  |
| 76.1 | 11.3 | 20.3 |  | μ |
| 76.2 | 12.2 | 21.9 | 8.94 | 34.0 |
| 76.0 | 13.8 | 24.0 |  |  |
| 76.1 | 13.2 | 22.0 |  |  |
|  | 13.2 | 20.8 |  |  |
|  | 13.0 |  |  |  |

Again. Draw-tube 4.0; 67.39 div. of scale=.002 inch.

| .002 inch. |  | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 67.2 | 67.8 | 27.2 | 34.8 |  |  |
| 67.0 | 67.7 | 27.3 | 35.0 |  |  |
| 67.4 | 66.9 | 26.9 | 34.2 | 7.70 | 33.1 |
| 67.3 | 67.2 | 27.2 | 35.1 |  |  |
| 67.5 | 67.9 | 27.7 | 35.1 |  |  |
|  |  | 27.2 | 35.9 |  |  |
|  |  | 28.0 |  |  |  |
| Again. |  |  |  |  |  |
|  |  | 28.9 | 37.0 |  |  |
|  |  | 28.5 |  |  |  |
|  |  | 28.0 | 36.0 |  |  |
|  |  | 28.1 | 36.0 |  |  |
|  |  | 28.2 | 37.0 |  |  |
|  |  | 28.3 | 37.8 |  |  |
|  |  | 29.9 | 38.0 |  |  |
|  |  | 30.0 | 38.1 | 8.23 | 35.4 |
|  |  | 30.0 | 38.1 |  |  |
|  |  | 30.1 | 38.0 |  |  |
|  |  | 30.5 | 38.0 |  |  |
|  |  | 29.1 | 37.9 |  |  |
|  |  | 30.0 | 40.0 |  |  |
|  |  | 32.3 | 41.0 |  |  |
|  |  | 33.0 | 41.1 |  |  |
|  |  | 33.2 |  |  |  |

Scale put on 46$^{cm}$.6 behind middle of knife-edge. Draw tube=0; 98.02 div. of scale=.004 inch.

| .004 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 97.9 | 38.2 | 22.4 |  |  |
| 97.7 | 37.8 | 22.2 |  |  |
| 97.9 | 38.2 | 22.2 |  | μ |
| 98.3 | 38.4 | 22.7 | 15.46 | 91.3 |
| 98.4 | 38.2 | 23.0 |  |  |
| 98.2 | 38.1 | 23.1 |  |  |
| 97.9 | 38.1 | 23.2 |  |  |
| 97.9 |  |  |  |  |

Again, tube=5.4; 37.94 div. of scale=.001 inch.

| .002 inch. | | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 76.0 | 75.9 | 33.1 | 10.1 | | |
| 76.2 | 75.5 | 33.2 | 9.0 | | $\mu$ |
| 75.9 | 76.1 | 33.0 | 9.7 | 23.20 | 88.5 |
| 76.2 | 76.2 | 33.1 | 9.1 | | |
| | 76.6 | 33.1 | 10.8 | | |
| | | 33.7 | 10.7 | | |
| | | 33.9 | | | |

Again.

| | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 75.1 | 41.6 | 18.3 | | |
| 75.3 | 41.5 | 18.1 | | |
| 75.8 | 41.6 | 18.0 | 23.40 | 89.2 |
| 76.0 | 42.0 | | | |
| 76.1 | 42.2 | 19.0 | | |

### 1879, November 19.

Scale 46$^{cm}$.6 *behind* agate. Tube 0; 96.96 div. of scale=.004 inch.

*Scale readings.*

| .004 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 97.0 | 28.9 | 14.4 | | |
| 96.9 | 29.3 | 14.7 | | |
| 97.1 | 29.1 | 15.0 | | $\mu$ |
| 96.8 | 29.8 | 15.8 | 14.44 | 86.3 |
| 97.0 | 30.1 | 15.7 | | |
| | 30.3 | 16.0 | | |
| | 30.4 | 15.7 | | |
| | 30.2 | 15.8 | | |
| | 30.0 | | | |

Again, tube=5.4; 74.69 div. of scale=.002 inch.

| .002 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 74.0 | 22.7 | 0.2 | | |
| 74.7 | 22.9 | 0.0 | | |
| 74.8 | 22.8 | 0.9 | | |
| 74.9 | 23.1 | 1.2 | 22.36 | 86.6 |
| 74.9 | 23.3 | 0.3 | | |
| 74.7 | 23.2 | 1.0 | | |
| | 22.3 | 0.5 | | |
| | 23.2 | 0.8 | | |
| | 23.2 | | | |

Again, tube 3.6; 98.7 div. of scale=.003 inch.

| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 98.7 | 36.9 | 17.1 | | |
| 98.7 | 36.8 | 16.8 | | |
| 98.7 | 36.3 | 16.8 | | |
| | 35.9 | 16.3 | 19.80 | 87.2 |
| | 36.0 | 16.2 | | |
| | 36.1 | 15.9 | | |
| | 35.0 | 15.3 | | |

Again, tube 1.8; 85.78 div. of scale=.003 inch.

| .003 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 85.7 | 36.1 | 19.1 | | |
| 86.0 | 36.0 | 19.0 | | μ |
| 85.8 | 36.8 | 19.9 | 17.01 | 86.1 |
| 85.5 | 36.1 | 19.0 | | |
| 85.9 | 36.1 | 19.0 | | |
| | 36.0 | | | |

NOTE.—When a wagon passes by on the street (ground somewhat frozen), the agitation of the apparatus is so violent that the lines wholly disappear. Tremor estimated at $5^{div}$ (sometimes even $12^{div}$, when a wagon is moving very rapidly and is exactly opposite); $1^{div}=0^{\mu}.889$.

Scale $46^{cm}.6$ in front. Tube 1.8; 85.08 div.=.003 inch.

| | | | | |
|---|---|---|---|---|
| 85.0 | 30.0 | 37.0 | | |
| 85.3 | 29.1 | 37.3 | | |
| 85.1 | 29.0 | 36.7 | | |
| 85.0 | 29.1 | 36.8 | | |
| 85.0 | 28.8 | 35.9 | 7.81 | 39.9 |
| | 28.0 | 36.7 | | |
| | 29.0 | 36.1 | | |
| | 28.8 | 36.7 | | |
| | 28.8 | 37.3 | | |
| | 29.2 | | | |

Again. Tube 4.8; 70.94 div. of scale=.002 inch.

| .002 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|---|
| 70.9 | 7.3 | 16.9 | | |
| 71.0 | 7.0 | 16.2 | | |
| 70.7 | 6.2 | 15.0 | | |
| 71.1 | 5.9 | 14.3 | | |
| 71.0 | 5.9 | | | |
| | 6.0 | 15.9 | 9.38 | 38.3 |
| | 5.8 | 14.4 | | |
| | 4.3 | 14.2 | | |
| | 5.3 | 14.3 | | |
| | 5.2 | 15.2 | | |
| | 4.3 | 14.3 | | |
| | 5.6 | 14.2 | | |
| | 5.0 | | | |

### 1879, NOVEMBER 23.

Flexure apparatus readjusted. Pieces of hoop iron substituted for heavier strips. So much agitation that experiments were postponed.

### 1879, NOVEMBER 26.

Scale $43^{cm}.5$ *forward* of middle of knife-edge, and $111^{cm}$ *below*. Tube 5, with $\frac{2}{3}$ objective; 98.9 div. of scale=.009 inch.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| .009 inch. | Wt. on. | Wt. off. | Diff. | $f_0$. |
| 98.8 | 11.1 | 23.0 | | |
| 98.4 | 10.9 | 23.7 | | |
| 98.9 | 9.7 | 22.2 | | μ |
| 99.0 | 9.2 | 20.7 | 12.73 | 167.6 |
| 99.0 | 7.9 | 20.0 | | |
| 99.1 | 6.5 | 19.4 | | |
| 99.0 | 6.2 | 18.9 | | |
| 99.0 | 5.7 | | | |

Summary of statical observations with weight and pulley made at York upon Geneva support. $F_0$=flexure at middle point of knife-edge; A=distance of middle point to intersection of axis with knife-edge; B=distance in a vertical line from middle point to axis.

$46^{cm}.6$ forward of knife-edge, $f_0= \overset{\mu}{38.6}$; Nov. 9, $\overset{\mu}{43.1}$; Nov. 13, $\overset{\mu}{38.7}$; Nov. 16, $\overset{\mu}{33.5}$; Nov. 19, $\overset{\mu}{39.1}$.
$46^{cm}.6$ back of knife-edge, $f_0=$ 87.7; Nov. 9, 86.7; Nov. 16, 89.7; Nov. 19. 86.6.
$43^{cm}.5$ forward, $111^{cm}$ below, $f_0$=167.6.
$\therefore F_0=$ 63.1.
$F_0 : A=10^{-4}\,0.527$ A=119.8.
$F_0 : B=10^{-4}\,1.148$ B= 54.9.

### 1879, DECEMBER 7.

Dynamical flexure. Scale $52^{cm}.5$ *behind* middle of knife-edge. In these and the following experiments the silver arc is always carefully placed with its zero exactly under the pendulum point at rest; 90.39 div. of scale=.003 inch.

| .003 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | μ |
| 90.0 | .0350 | 9.2 | 13.7 | 4.5 | 77.6 |
| 90.7 | 346 | 10.1 | 14.6 | 4.5 | 78.3 |
| 90.5 | 341 | 10.3 | 13.9 | 3.6 | 63.2 |
| 90.0 | 330 | 13.0 | 16.8 | 3.8 | 69.2 |
| 90.4 | 328 | 12.4 | 16.5 | 4.1 | 75.2 |
| 90.9 | 325 | 12.4 | 15.8 | 3.4 | 62.6 |
| 90.2 | 319 | 12.3 | 16.1 | 3.8 | 71.6 |
| | 296 | 16.2 | 20.0 | 3.8 | 77.1 |
| | 294 | 14.8 | 18.2 | 3.4 | 69.2 |
| | 292 | 15.1 | 18.8 | 3.7 | 76.5 |
| | 290 rej. | 13.8 | 18.2 | | .... |
| | 285 | 16.3 | 19.1 | 2.8 | .... |
| | 282 | 15.4 | 18.4 | 3.0 | 63.8 |
| | 280 | 17.0 | 20.2 | 3.2 | 68.6 |
| | 278 | 17.0 | 20.2 | 3.2 | 71.6 |
| | 269 | 17.0 | 20.4 | 3.4 | 75.9 |
| | | | | | 71.5 |

### 1879, DECEMBER 14.

Scale $52^{cm}.5$ *behind;* 1 div. of scale=$0^{\mu}.843$; dynamical.

| Arc. | Scale readings. | | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | μ |
| .0374 | 29.5 | 24.7 | | 4.8 | 77.1 |
| 369 | 32.3 | 27.8 | | 4.5 | 73.4 |
| 365 | 6.8 | 2.7 | | 4.1 | 67.4 |
| 361 | 8.9 | 4.2 | | 4.7 | 78.9 |
| 352 | 11.9 | 8.2 | | 3.7 | 63.2 |
| 348 | 13.1 | 8.8 | | 4.3 | 74.0 |
| 344 | 14.7 | 10.8 | | 3.9 | 68.0 |
| 341 | 16.2 | 12.3 | | 3.9 | 68.6 |
| 321 | 11.2 | 7.2 | | 4.0 | 74.6 |
| 319 | 11.6 | 7.8 | | 3.8 | 71.6 |
| 317 | 11.3 | 7.5 | | 3.8 | 72.2 |
| 314 | 11.3 | 7.3 | | 4.0 | 76.5 |
| 310 | 11.0 | 7.1 | | 3.9 | 75.9 |
| 309 | 12.0 | 7.9 | | 4.1 | 80.1 |
| 308 | 10.8 | 7.0 | | 3.8 | 74.0 |
| 306 | 10.8 | 7.2 | good | 3.6 | 70.2 |
| 305 | 10.8 | 7.1 | | 3.7 | 72.8 |
| | | | | | 72.9 |

Again, evening; 81 div. of scale=.003 inch.

| .003 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | $\mu$ |
| 80.9 | .0353 | 4.2 | 0.3 | 3.9 | 73.9 |
| 81.0 | 351 | 3.9 | 0.2 | 3.7 | 70.6 |
| 81.0 | 350 | 4.9 | 1.1 | 3.8 | 73.2 |
| | 348 | 5.0 | 1.2 | 3.8 | 73.2 |
| | 345 | 5.0 | 1.4 | 3.6 | 69.9 |
| | 342 | 13.3 | 9.7 | 3.6 | 70.6 |
| | 339 | 13.1 | 9.8 | 3.3 | 65.2 |
| | 335 | 13.4 | 9.8 | 3.6 | 71.9 |
| | 333 | 13.6 | 10.0 | 3.6 | 72.6 |
| | 330 | 14.4 | 10.7 | 3.7 | 75.3 |
| | 328 | 14.0 | 11.0 | 3.0 | 61.2 |
| | 325 | 14.8 | 11.2 | 3.6 | 74.6 |
| | | | | | 71.2 |

Statical flexure. Same position as before; 35 div. of scale=.001 inch. Readings taken in two positions of pendulum, zero and .0370 out.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| .002 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 70.0 | .0370 | 0.7 | 3.2 | | |
| 70.0 | | 0.2 | 2.9 | | |
| | | 0.2 | 2.3 | | |
| | | 0.0 | 3.0 | div. | $\mu$ |
| | | 0.2 | 3.0 | 2.50 | 70.0 |
| | | 0.1 | 2.4 | | |
| | | 0.3 | 2.9 | | |
| | | 0.2 | 2.3 | | |
| | | −0.1 | 2.0 | | |
| | | −0.1 | 1.9 | | |
| | | −0.9 | 1.7 | | |
| | | −0.8 | 1.6 | | |
| | | −0.9 | | | |

Scale 46$^{\text{cm}}$.0 in front of knife-edge; 69.74 div.=.002 inch.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| .002 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 69.8 | .0370 | 27.0 | 25.1 | | |
| 70.4 | | 26.3 | 24.9 | | |
| 69.1 | | 25.8 | 23.9 | | |
| 69.7 | | 25.3 | 23.8 | | |
| 69.6 | | 25.3 | 23.2 | div. | $\mu$ |
| 69.2 | | 23.9 | 22.2 | 1.65 | 46.6 |
| 70.2 | | 23.2 | 22.2 | | |
| 69.9 | | 23.1 | 21.6 | | |
| 69.8 | | 23.0 | 21.0 | | |
| | | 23.0 | 21.5 | | |
| | | 22.6 | 20.8 | | |
| | | 22.4 | 20.9 | | |

Dynamical flexure. Scale $46^{cm}.0$ in front of middle of knife-edge; 34.72 div. of scale=.001 inch.

| .002 inch. | Arc. | Scale readings. | | Mean diff. | $f_0$. μ |
|---|---|---|---|---|---|
| 69.6 | .0363 | 25.3 | 22.3 | 3.0 | 43.2 |
| 69.3 | 359 | 24.8 | 21.8 | 3.0 | 43.7 |
| 69.4 | 356 | 24.3 | 21.4 | 2.9 | 42.6 |
| | 350 | 22.6 | 20.0 | 2.6 | 39.0 |
| | 343 | 21.9 | 19.7 | 2.2 | 33.5 |
| | 334 | 20.1 | 17.9 | 2.2 | 34.5 |
| | 329 | 19.5 | 17.0 | 2.5 | 39.7 |
| | 323 | 18.8 | 16.3 | 2.5 | 40.5 |
| | 319 | 18.5 | 15.7 | 2.8 | 45.9 |
| | 309 | 25.0 | 21.8 | 3.2 | .... |
| | 305 | 22.0 | 19.3 | 2.7 | 46.3 |
| | 293 | 22.9 | 20.3 | 2.6 | 46.4 |
| | 279 | 22.0 | 20.2 | 1.8 | 33.7 |
| | 276 | 21.1 | 19.5 | 1.6 | .... |
| | 274 | 21.7 | 19.4 | 2.3 | 43.9 |
| | 270 | 23.0 | 21.2 | 1.8 | 34.9 |
| | 261 | 23.7 | 21.6 | 2.1 | 42.0 |
| | | | | | 41.0 |

1879, DECEMBER 15.

Statical flexure. Scale $46^{cm}.0$ in front of middle of knife-edge; 34.57 div. of scale=.001 inch.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| .002 inch. | Arc. | Out. | Zero. | Mean diff. | $f_0$. |
| 69.1 | .0370 | 16.0 | 17.3 | | |
| 69.1 | | 13.5 | 14.7 | | |
| 69.2 | | 12.7 | 13.4 | | |
| | | 11.5 | 12.8 | | |
| | | 11.0 | 12.1 | | |
| | | 10.8 | 11.9 | div. | μ |
| | | 9.2 | 10.5 | 1.125 | 32.0 |
| | | 9.8 | 11.0 | | |
| | | 9.1 | 10.0 | | |
| | | 8.2 | 9.1 | | |
| | | 7.6 | 8.7 | | |
| | | 22.9 | 24.1 | | |
| | | 20.9 | 22.2 | | |
| | | 20.1 | 21.2 | | |
| | | 18.9 | 20.0 | | |
| | | 17.8 | 19.0 | | |

Dynamical flexure; $46^{cm}.0$ in *front;* 34.57 div. of scale=.001 inch.

| Arc. | Scale readings. | | Diff. | $f_0$. μ |
|---|---|---|---|---|
| .0356 | 18.0 | 20.7 | 2.7 | 39.8 |
| 352 | 16.3 | 18.8 | 2.5 | 37.3 |
| 348 | 14.0 | 16.8 | 2.8 | 42.3 |
| 341 | 13.8 | 16.3 | 2.5 | 38.5 |
| 338 | 14.9 | 17.1 | 2.2 | 34.2 |
| 334 | 12.8 | 15.2 | 2.4 | 37.7 |
| 323 | 13.5 | 16.0 | 2.5 | 40.6 |

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | $\mu$ |
| 321 | 12.5 | 14.8 | 2.3 | 39.5 |
| 319 | 12.0 | 14.4 | 2.4 | 43.6 |
| 313 | 11.2 | 13.8 | 2.6 | 39.1 |
| 309 | 11.6 | 13.9 | 2.3 | 39.6 |
| 305 | 10.9 | 13.2 | 2.3 | 36.9 |
| 299 | 9.9 | 12.0 | 2.1 | |
| | | | | 39.1 |

Dynamical flexure; $52^{cm}.5$ *behind* middle of knife-edge; 35.35 div. of scale=.001 inch.

| .002 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | $\mu$ |
| 70.7 | .0355 | 11.9 | 16.7 | 4.8 | 69.3 |
| 70.7 | 351 | 10.4 | 14.8 | 4.4 | 64.1 |
| | 347 | 10.1 | 14.4 | 4.3 | 63.6 |
| | 345 | 9.9 | 14.2 | 4.3 | 64.1 |
| | 341 | 9.2 | 13.7 | 4.5 | 67.7 |
| | 338 | 9.6 | 13.9 | 4.3 | 65.2 |
| | 334 | 8.8 | 13.3 | 4.5 | 69.3 |
| | 331 | 8.8 | 13.2 | 4.4 | 68.2 |
| | 316 | 8.3 | 12.7 | 4.4 | 71.3 |
| | 312 | 8.7 | 12.9 | 4.2 | 68.7 |
| | 310 | 8.8 | 12.8 | 4.0 | 66.2 |
| | 308 | 8.0 | 12.2 | 4.2 | 69.8 |
| | 305 | 8.0 | 12.1 | 4.1 | 69.3 |
| | 302 | 8.5 | 12.4 | 3.9 | 66.2 |
| | | | | | 67.4 |

Statical flexure. Same conditions as above.

| Arc. | *Scale readings.* Out. | Zero. | Mean diff. | $f_0$. |
|---|---|---|---|---|
| .0370 | 9.6 | 7.4 | | |
| | 9.3 | 7.2 | | |
| | 9.2 | 6.9 | | |
| | 9.0 | 6.8 | | |
| | 8.4 | 6.4 | div. | $\mu$ |
| | 8.4 | 6.2 | 2.21 | 61.3 |
| | 9.3 | 7.1 | | |
| | 9.8 | 7.2 | | |
| | 7.0 | 4.8 | | |
| | 6.9 | 4.7 | | |
| | 6.9 | 4.8 | | |
| | 6.7 | 4.5 | | |

Statical flexure. Scale $52^{cm}.5$ behind middle of knife-edge; 34.3 div. of scale=.001 inch. *Binding-screws all loosened.*

| .002 inch. | Arc. | *Scale readings.* Out. | Zero. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 68.6 | .0370 | 27.4 | 25.1 | | |
| 68.6 | | 27.7 | 25.2 | div. | $\mu$ |
| | | 27.1 | 24.6 | 2.48 | 70.9 |
| | | 26.8 | 24.3 | | |
| | | 26.8 | 24.4 | | |
| | | 26.4 | 23.7 | | |

Dynamical flexure. Same condition as above.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | $\mu$ |
| .0335 | 21.9 | 26.4 | 4.5 | 71.0 |
| 330 | 21.7 | 26.3 | 4.6 | 73.7 |
| 327 | 21.7 | 26.1 | 4.4 | 71.2 |
| 321 | 21.2 | 25.5 | 4.3 | 70.9 |
| 318 | 21.3 | 25.2 | 3.9 | 64.9 |
| 312 | 21.0 | 24.8 | 3.8 | 64.4 |
| | | | | 69.4 |

Scale $46^{cm}.0$ in front of middle of knife-edge; 33.83 div. of scale=.001 inch. *Binding-screws loose;* dynamical flexure.

| .002 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | $\mu$ |
| 67.6 | .0362 | 15.0 | 17.7 | 2.7 | 40.0 |
| 67.7 | 358 | 12.7 | 15.8 | 3.1 | 46.4 |
| | 335 | 6.7 | 8.8 | 2.1 | 33.6 |
| | 334 | 4.7 | 7.0 | 2.3 | 36.9 |
| | 329 | 2.1 | 4.7 | 2.6 | 42.4 |
| | 325 | 3.0 | 5.7 | 2.7 | 44.5 |
| | | | | | 40.6 |

Statical flexure under same conditions.

| Arc. | *Scale readings.*<br>Out. | Zero. | Mean diff. | $f_0$. |
|---|---|---|---|---|
| .0370 | 29.0 | 29.9 | | |
| | 23.9 | 25.0 | | |
| | 19.7 | 20.6 | div. | $\mu$ |
| | 19.7 | 19.2 | 1.10 | 31.9 |
| | 17.1 | 18.1 | | |
| | 15.6 | 16.7 | | |
| | 14.4 | 15.6 | | |

Summary of observations, dynamical and statical, made at York, with pendulum on Geneva support.

*Screws wrenched.*

| | | Dynam. | Stat. |
|---|---|---|---|
| $46^{cm}.0$ forward of knife-edge, | $f_0=$ | $40^{\mu}.0$ | $39^{\mu}.3$ |
| $52^{cm}.5$ back of knife-edge, | $f_0=$ | $70^{\mu}.7$ | $65^{\mu}.7$ |
| | $\therefore F_0=$ | $56^{\mu}.4$ | $53^{\mu}.4$ |
| | A= | $181^{cm}$ | $199^{cm}$ |
| | $F_0$ : A | 0.312 | 0.268 |

*Screws loose.*

| | | Dynam. | Stat. |
|---|---|---|---|
| $46^{cm}.0$ forward of knife-edge, | $f_0=$ | $40^{\mu}.6$ | $31^{\mu}.9$ |
| $52^{cm}.5$ back of knife-edge, | $f_0=$ | $69^{\mu}.4$ | $70^{\mu}.9$ |
| | $\therefore F_0=$ | $59^{\mu}.9$ | $52^{\mu}.7$ |
| | A= | $192^{cm}$ | $133^{cm}$ |
| | $F_0$ : A | 0.292 | 0.396 |

The statical measures are evidently unreliable. The dynamical measures show that the binding screws have no effect.

### 1879, DECEMBER 21.

Repsold stand; the three legs hand-tightened both above and below. Statical observations with weight and pulley; weight used=$1^k$; 27.78 div. of scale=.001 inch. Scale $56^{cm}.7$ in front of knife-edge.

| | | *Scale readings.* | | | | |
|---|---|---|---|---|---|---|
| .003 inch. | | Wt. on. | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
| 82. 8 | 83. 2 | 16. 6 | 80. 7 | 16. 8 | div. | μ |
| 83. 8 | 83. 3 | 10. 1 | 73. 9 | 9. 9 | 63. 95 | 368. 8 |
| 84. 1 | 83. 2 | 4. 0 | 67. 5 | 2. 8 | | |
| 83. 0 | | 4. 2 | 67. 9 | 3. 8 | | |
| | | 13. 2 | 76. 7 | 12. 4 | | |

Now wrench-tightened below and hand-tightened above; 27.78 div. of scale=.001 inch.

| | | | | |
|---|---|---|---|---|
| 16. 7 | 76. 9 | 15. 3 | div. | μ |
| 12. 2 | 73. 9 | 12. 8 | 61. 16 | 352. 7 |
| 8. 1 | 69. 2 | 7. 9 | | |

Microscope refocused; 27.47 div. of scale=.001 inch.

| | .003 inch. | | Wt. on. | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|---|---|
| 82. 2 | 82. 6 | 82. 6 | 20. 3 | 80. 4 | 19. 1 | div. | μ |
| 81. 9 | 82. 4 | 82. 7 | 19. 8 | 80. 0 | 20. 2 | 60. 2 | 351. 2 |
| | | | 20. 7 | 80. 2 | 19. 9 | | |

Nuts again wrench-tightened both above and below; 27.77 div. of scale=.001 inch.

| .003 inch. | Wt. on | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 83. 3 | 27. 2 | 88. 8 | 27. 4 | | |
| 83. 3 | 27. 2 | 88. 4 | 26. 8 | div. | μ |
| 83. 3 | 23. 4 | 84. 2 | 23. 4 | 61. 22 | 353. 3 |
| | 20. 6 | 81. 8 | 20. 0 | | |
| | 19. 1 | 79. 8 | 18. 7 | | |

Scale $50^{cm}.1$ behind middle of knife-edge. Nuts still wrench-tightened; 27.74 div. of scale=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 83. 2 | 14. 3 | 43. 5 | 14. 9 | | |
| 83. 2 | 15. 1 | 44. 0 | 15. 9 | div. | μ |
| 83. 3 | 16. 3 | 45. 4 | 16. 5 | 28. 82 | 166. 5 |
| 83. 2 | 17. 5 | 46. 3 | 17. 5 | | |
| | 19. 0 | 47. 9 | 19. 0 | | |

Wrench-tightened below, hand-tightened above.

| | | | | |
|---|---|---|---|---|
| 26. 7 | 58. 3 | 27. 3 | | |
| 3. 7 | 36. 2 | 3. 7 | div. | μ |
| 2. 3 | 34. 8 | 2. 5 | 32. 05 | 185. 2 |
| 1. 8 | 34. 0 | 1. 6 | | |
| 1. 4 | 33. 2 | 1. 2 | | |
| 1. 1 | 33. 0 | 1. 1 | | |

Evening. Nuts hand-tightened above and below; 27.72 div.=.001 inch.

| | | | | | |
|---|---|---|---|---|---|
| 83. 1 | 25. 5 | 57. 2 | 25. 1 | | |
| 83. 2 | 23. 8 | 56. 0 | 23. 8 | div. | μ |
| 83. 2 | 23. 3 | 55. 2 | 22. 9 | 32. 08 | 185. 4 |
| | 22. 0 | 54. 2 | 21. 8 | | |
| | 21. 5 | 53. 3 | 21. 3 | | |

Nuts wrench-tightened below, also on hind leg above, but the two front legs hand-tightened Feet tightened very slightly. 27.72 div. of scale=.001 inch.

| .003 inch. | Wt. on. | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
|  | 11. 5 | 36. 7 | 11. 5 |  |  |
|  | 10. 4 | 35. 2 | 10. 0 | div. | μ |
|  | 10. 1 | 34. 9 | 9. 9 | 25. 08 | 145. 0 |
|  | 9. 0 | 34. 2 | 9. 2 |  |  |
|  | 8. 7 | 33. 9 | 8. 7 |  |  |

Again. Wrench-tightened above and below; 27.58 div. of scale=.001 inch.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| 82. 6 | 10. 1 | 41. 4 | 9. 7 |  |  |
| 82. 9 | 9. 8 | 41. 1 | 9. 8 | div. | μ |
| 82. 7 | 9. 0 | 40. 3 | 9. 2 | 31. 20 | 181. 2 |
|  | 9. 2 | 40. 2 | 9. 2 |  |  |
|  | 9. 0 | 40. 1 | 9. 2 |  |  |

Again. Binding-screws of the three feet quite loose. 27.58 div. of scale=.001 inch.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 6. 3 | 39. 2 | 7. 1 |  |  |
|  | 6. 3 | 38. 2 | 6. 3 | div. | μ |
|  | 5. 0 | 36. 9 | 4. 4 | 32. 24 | 187. 3 |
|  | 4. 0 | 36. 1 | 4. 0 |  |  |
|  | 3. 7 | 36. 0 | 3. 3 |  |  |

Binding-screws tight as possible.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 29. 9 | 59. 8 | 29. 7 |  |  |
|  | 29. 1 | 59. 0 | 28. 5 | div. | μ |
|  | 27. 6 | 57. 4 | 27. 8 | 29. 94 | 173. 9 |
|  | 27. 3 | 57. 1 | 26. 9 |  |  |
|  | 26. 5 | 56. 3 | 26. 5 |  |  |

Weight of 2.7 kilos put on stand above.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 12. 4 | 42. 1 | 11. 5 | div. | μ |
|  | 9. 2 | 38. 9 | 9. 0 | 29. 84 | 173. 4 |
|  | 8. 0 | 37. 5 | 7. 2 |  |  |
|  | 6. 0 | 35. 3 | 5. 2 |  |  |
|  | 3. 8 | 33. 4 | 3. 4 |  |  |

Scale 56$^{cm}$.7 in front of knife-edge. Nuts tightened. Same weight on top of stand; 27.83

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| 83. 6 | 20. 9 | 81. 0 | 19. 7 |  |  |
| 83. 3 | 13. 8 | 74. 5 | 13. 6 | div. | μ |
| 83. 6 | 11. 0 | 71. 7 | 10. 6 | 60. 66 | 349. 2 |
|  | 6. 4 | 66. 4 | 5. 2 |  |  |
|  | 1. 3 | 61. 4 | 0. 9 |  |  |

Weight removed from top of stand; otherwise same as above; 27.83 div.=.001 inch.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
|  | 32. 0 | 92. 4 | 31. 4 |  |  |
|  | 26. 8 | 87. 4 | 25. 8 | div. | μ |
|  | 23. 1 | 83. 7 | 22. 3 | 60. 99 | 350. 6 |
|  | 13. 3 | 73. 8 | 12. 7 |  |  |
|  | 10. 8 | 71. 5 | 10. 4 |  |  |

Binding-screws loosened; 28.09 div. of scale=.001 inch.

|  |  |  |  |  |  |
|---|---|---|---|---|---|
| 84. 6 | 30. 0 | 95. 1 | 28. 2 |  |  |
| 84. 0 | 27. 2 | 92. 5 | 26. 2 |  |  |
| 84. 3 | 23. 6 | 88. 7 | 22. 4 | div. | μ |
| 84. 2 | 19. 8 | 84. 9 | 18. 6 | 65. 66 | 374. 6 |
|  | 17. 1 | 82. 3 | 16. 5 |  |  |
|  | 15. 1 | 80. 4 | 14. 5 |  |  |
|  | 13. 6 | 78. 8 | 13. 4 |  |  |

Binding-screws *moderately tightened* (about as in earlier experiments).

| Wt. on. | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
|---|---|---|---|---|
| 32.5 | 93.2 | 31.9 | | |
| 31.4 | 92.0 | 30.8 | | |
| 30.4 | 91.0 | 30.2 | div. | μ |
| 28.1 | 88.9 | 27.7 | 61.03 | 348.1 |
| 25.8 | 86.7 | ... | | |
| 27.0 | 88.4 | 26.8 | | |
| 26.7 | 87.7 | 26.5 | | |

Nuts at top of two front legs hand-tightened; 28.11 div. of scale=.001 inch.

| .003 inch. | Wt. on. | Wt. off. | Wt. on. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 84.0 | 15.4 | 88.6 | 15.2 | | |
| 84.7 | 13.4 | 87.2 | 13.6 | div. | μ |
| 84.3 | 16.5 | 90.2 | 16.1 | 73.76 | 420.5 |
| 84.3 | 15.7 | 88.7 | 14.7 | | |
| | 13.6 | 87.8 | 13.2 | | |

NOTE.—The weight put on stand was a very heavy paper weight. Observer troubled all day by tremor; every passer by on the street, every one entering the building, or even the adjoining building, agitates the apparatus so as to make it impossible to read the scale.

Summary of observations with weight and pulley, on Repsold stand, at York.

| | Nuts hand-tightened above and below. | Nuts hand above, wrench below. | Nuts wrenched above and below. | Binding-screws extra tight. | Binding-screws loose. | Weight on. |
|---|---|---|---|---|---|---|
| $56^{\text{cm}}.4$ forward, | $368^{\mu}.8$ | $351^{\mu}.9$ | $350^{\mu}.7$ | $350^{\mu}.6$ | $374^{\mu}.6$ | $349^{\mu}.2$ |
| $50^{\text{cm}}.1$ behind middle point, | $185^{\mu}.4$ | $185^{\mu}.2$ | $173^{\mu}.9$ | $173^{\mu}.9$ | $187^{\mu}.3$ | $173^{\mu}.4$ |
| $50^{\text{cm}}.1$ behind middle point, | $271^{\mu}\ 4$ | $263^{\mu}.6$ | $256^{\mu}.9$ | $256^{\mu}.8$ | $275^{\mu}.2$ | $255^{\mu}.9$ |
| A, | $158^{\text{cm}}$ | $168^{\text{cm}}$ | $156^{\text{cm}}$ | $156^{\text{cm}}$ | $147^{\text{cm}}$ | $156^{\text{cm}}$ |
| $F_0$ : A, | 1.72 | 1.57 | 1.65 | 1.65 | 1.75 | 1.65 |

## 1879, DECEMBER 23.

Evening. Still very tremulous; especially when vehicles pass, as they frequently do. Scale $56^{\text{cm}}.6$ in front. All tightly wrenched up. No weight on top of stand. Measures all very uncertain. 27.89 div. of scale=.001 inch. Dynamical flexure.

| .003 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| | | | | | μ |
| 83.5 | .0461 | 4.2 | 28.8 | 24.6 | 348 |
| 83.8 | 450 | 5.7 | 29.2 | 23.5 | 340 |
| 83.7 | 433 | 5.2 | 27.8 | 22.6 | 340 |
| | 427 | 5.3 | 27.7 | 22.4 | 342 |
| | 420 | 6.0 | 27.5 | 21.5 | 333 |
| | 393 | 6.5 | 27.0 | 20.5 | 340 |
| | 377 | 6.2 | 26.1 | 19.9 | 344 |
| | 368 | 5.3 | 24.7 | 19.4 | 343 |
| | 353 | 7.3 | 25.8 | 18.5 | 341 |
| | 347 | 7.3 | 25.6 | 18.3 | 342 |
| | 323 | 7.6 | 24.4 | 16.8 | 339 |
| | | | | | 342.4 |

Statical flexure, with same arrangement.

|  | *Scale readings.* |  |  |  |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 3.2 | 16.6 |  |  |
|  | 3.7 | 17.0 |  |  |
|  | 2.9 | 16.2 |  |  |
|  | 27.2 | 39.9 |  | μ |
|  | 25.9 | 38.7 | 13.08 | 340.4 |
|  | 26.3 | 39.0 |  |  |
|  | 24.9 | 38.4 |  |  |
|  | 24.8 | 38.0 |  |  |
|  | 26.4 | 39.2 |  |  |

1879, DECEMBER 25.

Morning. Arrangement same as in last observation. Scale 56$^{cm}$.6 in front of middle of knife-edge; 25.67 div. of scale=.001 inch. Statical flexure.

|  |  | *Scale readings.* |  |  |  |
|---|---|---|---|---|---|
| .003 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 77.2 | .0500 | 22.3 | 23.8 |  |  |
| 77.0 |  | 21.3 | 32.2 |  |  |
| 76.9 |  | 22.2 | 33.8 |  |  |
| 76.9 |  | 20.8 | 32.1 | div. | μ |
|  |  | 21.4 | 32.9 | 11.53 | 326.4 |
|  |  | 20.6 | 32.5 |  |  |
|  |  | 20.7 | 32.5 |  |  |
|  |  | 27.4 | 39.0 |  |  |
|  |  | 20.5 | 32.2 |  |  |
|  |  | 20.8 | 32.3 |  |  |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. |  | Diff. | $f_0$. |
|---|---|---|---|---|
|  |  |  |  | μ |
| .0485 | 17.7 | 39.4 | 21.7 | 316 |
| 478 | 17.1 | 38.8 | 21.7 | 321 |
| 440 | 17.3 | 38.4 | 21.1 | 339 |
| 431 | 19.2 | 39.0 | 19.8 | 325 |
| 325 | 19.7 | 33.3 | 13,6 | 296 |
| 320 | 19.8 | 34.8 | 15.0 | 332 |
| 315 | 20.8 | 35.1 | 14.3 | 321 |
| 269 | 5.4 | 17.4 | 12.0 | 315 |
|  |  |  |  |  |
| 506 | 20.8 | 44.8 | 24.0 | 335 |
| 502 | 22.3 | 45.8 | 23.5 | 331 |
| 500 | 22.6 | 45.1 | 22.5 | 318 |
| 497 | 20.7 | 43.9 | 23.2 | 330 |
| 494 | 21.9 | 44.4 | 22.5 | 322 |
| 472 | 22.2 | 43.4 | 21.2 | 317 |
| 469 | 22.0 | 43.9 | 21.9 | 330 |
| 465 | 21.7 | 43.2 | 21.5 | 327 |
| 462 | 22.8 | 43.6 | 20.8 | 318 |
| 458 | 23.0 | 43.6 | 20.6 | 318 |
|  |  |  |  | 323.5 |

### 1880, JANUARY 4.

Same arrangement and position as in last observed; 25.72 div. of scale=.001 inch; statical flexure.

*Scale readings.*

| .300 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 77.3 | .0500 | 21.1 | 9.8 | div. | μ |
| 77.1 | | 21.2 | 10.0 | 11.43 | 323.9 |
| 77.1 | | 20.1 | 8.4 | | |
| | | 15.0 | 3.5 | | |

Statical flexure again. Scale $50^{cm}.5$ behind middle of knife-edge.

| | | | | |
|---|---|---|---|---|
| .0500 | 16.5 | 22.3 | | |
| | 16.3 | 22.3 | | |
| | 16.4 | 22.5 | div. | μ |
| | 19.0 | 25.2 | 6.09 | 172.4 |
| | 18.8 | 24.8 | | |
| | 18.8 | 24.9 | | |
| | 19.1 | 25.4 | | |
| | 18.9 | 25.1 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0427 | 22.6 | 13.9 | 8.7 | 145 |
| 419 | 99.4 | 90.3 | 9.1 | 154 |
| 386 | 23.8 | 15.7 | 8.1 | 149 |
| 360 | 23.8 | 16.0 | 7.8 | 154 |
| 357 | 23.7 | 16.0 | 7.7 | 153 |
| 351 | 74.5 | 66.8 | 7.7 | 155 |
| 348 | 74.3 | 66.8 | 7.5 | 153 |
| 480 | 75.3 | 64.9 | 10.4 | 154 |
| 474 | 75.1 | 64.7 | 10.4 | 155 |
| 463 | 74.8 | 65.0 | 9.8 | 151 |
| 455 | 100.0 | 90.3 | 9.7 | 151 |
| 448 | 100.2 | 90.8 | 9.4 | 149 |
| 441 | 74.2 | 65.1 | 9.1 | 146 |
| 438 | 74.0 | 64.9 | 9.1 | 148 |
| 433 | 73.6 | 64.6 | 9.0 | 148 |
| | | | | 150.6 |

Two front nuts at top hand-tightened; 25.64 div. of scale=.001 inch. Statical flexure.

*Scale readings.*

| .003 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 77.0 | .0500 | 18.0 | 22.3 | | |
| 76.9 | | 18.0 | 22.2 | div. | μ |
| 76.9 | | 19.1 | 23.5 | 4.30 | 121.7 |
| | | 71.2 | 75.4 | | |
| | | 19.0 | 23.4 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0509 | 22.8 | 15.6 | 7.2 | 100 |
| 500 | 23.0 | 15.5 | 7.5 | 106 |
| 489 | 22.3 | 15.3 | 7.0 | 102 |
| 484 | 22.4 | 15.3 | 7.1 | 104 |
| 479 | 48.4 | 41.3 | 7.1 | 105 |
| 467 | 48.2 | 41.3 | 6.9 | 105 |
| 460 | 48.1 | 41.2 | 6.9 | 106 |
| | | | | 104.1 |

Stand wrench-tightened above, two front feet loosened below; 25.54 div. of scale=.001 inch. Statical flexure.

| .003 inch. | Arc. | Scale readings.<br>Zero. | <br>Out. | Mean diff. | $f_0$. |
|---|---|---|---|---|---|
| 76.6 | .0500 | 21.1 | 27.7 | | |
| 76.6 | | 21.0 | 27.6 | | |
| 76.7 | | 21.0 | 27.8 | div. | μ |
| | | 72.9 | 80.0 | 6.81 | 193.0 |
| | | 73.0 | 79.8 | | |
| | | 21.2 | 28.1 | | |
| | | 21.0 | 27.9 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0496 | 48.2 | 35.8 | 12.4 | 177 |
| 469 | 24.3 | 12.4 | 11.9 | 180 |
| 466 | 24.7 | 13.0 | 11.7 | 178 |
| 457 | 24.7 | 13.0 | 11.7 | 181 |
| 450 | 25.0 | 13.8 | 11.2 | 176 |
| 442 | 25.1 | 14.2 | 10.9 | 175 |
| 437 | 25.2 | 14.4 | 10.8 | 175 |
| 427 | 25.4 | 14.8 | 10.6 | 176 |
| | | | | 177.1 |

All wrench-tightened. Weight of 2,700$^{g}$ put on top of stand; otherwise same as preceding. Statical flexure.

| Arc. | Scale readings.<br>Zero. | <br>Out. | Mean diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 3.8 | 10.0 | | |
| | 30.3 | 36.5 | | |
| | 31.2 | 36.8 | | |
| | 6.2 | 12.3 | div. | μ |
| | 6.9 | 12.6 | 5.82 | 164.9 |
| | 7.5 | 13.0 | | |
| | 33.6 | 39.2 | | |
| | 8.4 | 14.2 | | |
| | 8.6 | 14.3 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0500 | 14.8 | 3.8 | 11.0 | 156 |
| 497 | 40.3 | 29.8 | 10.5 | 149 |
| 491 | 40.5 | 30.2 | 10.3 | 149 |
| 484 | 40.2 | 30.3 | 9.9 | 145 |
| 465 | 14.7 | 5.0 | 9.7 | 148 |
| 460 | 40.2 | 30.6 | 9.6 | 148 |
| 451 | 14.4 | 4.9 | 9.5 | 149 |
| 448 | 14.4 | 5.1 | 9.3 | 147 |
| 444 | 39.8 | 30.9 | 8.9 | 142 |
| | | | | 148.1 |

Evening. Scale $56^{cm}.8$ in front of middle of knife-edge. Statical flexure.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 15.2 | 3.6 | | |
| | 15.3 | 3.6 | | |
| | 16.0 | 4.0 | div. | μ |
| | 15.8 | 4.0 | 11.75 | 332.7 |
| | 15.8 | 3.9 | | |
| | 67.3 | 55.9 | | |
| | 67.6 | 55.8 | | |
| | 67.7 | 55.9 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0501 | 29.2 | 5.4 | 23.8 | 336 |
| 496 | 28.6 | 5.7 | 22.9 | 327 |
| 486 | 28.1 | 5.4 | 22.7 | 331 |
| 475 | 27.8 | 5.8 | 22.0 | 328 |
| 471 | 27.8 | 6.0 | 21.8 | 328 |
| 469 | 27.7 | 5.9 | 21.8 | 329 |
| 462 | 27.6 | 6.1 | 21.5 | 329 |
| 454 | 26.7 | 5.8 | 20.9 | 326 |
| 423 | 26.6 | 6.9 | 19.7 | 330 |
| 416 | 26.3 | 7.0 | 19.3 | 329 |
| 411 | 26.0 | 6.9 | 19.1 | 329 |
| | | | | 329.1 |

Weight taken off from top of stand. Two front feet loosened; 25.63 div. of scale=.001 inch. Statical.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| .003 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 76.5 | .0500 | 23.6 | 11.3 | | |
| 77.0 | | 23.5 | 11.2 | div. | μ |
| 76.9 | | 23.5 | 11.5 | 12.17 | 344.6 |
| | | 23.4 | 11.3 | | |
| | | 23.2 | 10.9 | | |
| | | 22.7 | 10.7 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0500 | 34.0 | 9.8 | 24.2 | 343 |
| 496 | 34.7 | 10.5 | 24.2 | 346 |
| 487 | 34.8 | 11.2 | 23.6 | 343 |
| 480 | 34.7 | 11.4 | 23.3 | 343 |
| 475 | 33.8 | 10.9 | 22.9 | 341 |
| 469 | 33.8 | 11.2 | 22.6 | 341 |
| 456 | 33.7 | 11.3 | 22.4 | 348 |
| 452 | 33.6 | 11.3 | 22.3 | 349 |
| | | | | 344.3 |

Feet of stand tightened, and two front legs hand-tightened above. Statical flexure; 25.54 div. of scale=.001 inch.

| | | Scale readings. | | | |
|---|---|---|---|---|---|
| .300 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 76.6 | .0500 | 29.8 | 15.3 | | |
| 76.7 | | 32.1 | 17.7 | div. | μ |
| 76.6 | | 32.3 | 18.0 | 14.34 | 406.0 |
| | | 31.8 | 17.4 | | |
| | | 32.7 | 18.6 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0512 | 47.0 | 18.2 | 28.8 | 398 |
| 506 | 47.7 | 19.0 | 28.7 | 401 |
| 500 | 47.7 | 19.7 | 28.0 | 396 |
| 488 | 47.5 | 20.1 | 27.4 | 397 |
| 475 | 46.6 | 20.3 | 26.3 | 392 |
| 468 | 47.0 | 20.7 | 26.3 | 398 |
| 463 | 46.7 | 20.8 | 25.9 | 396 |
| 451 | 46.7 | 21.4 | 25.3 | 397 |
| 443 | 47.7 | 22.7 | 25.0 | 399 |
| | | | | 397.4 |

Three thicknesses of blotting-paper put under each foot of pendulum stands. All nuts tight Otherwise same as preceding. Statical flexure.

| | Scale readings. | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 21.8 | 8.7 | | |
| | 22.0 | 8.5 | | |
| | 22.1 | 8.6 | | |
| | 19.3 | 6.6 | div. | μ |
| | 21.5 | 8.1 | 13.36 | 379.6 |
| | 21.7 | 7.9 | | |
| | 21.1 | 7.4 | | |
| | 22.3 | 8.8 | | |
| | 21.3 | 8.3 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| 0.509 | 27.7 | 1.3 | 26.4 | 367 |
| 494 | 53.9 | 28.7 | 25.2 | 361 |
| 482 | 54.0 | 29.2 | 24.8 | 365 |
| 477 | 53.7 | 29.4 | 24.3 | 360 |
| 461 | 53.3 | 29.7 | 23.6 | 362 |
| 457 | 53.7 | 30.0 | 23.7 | 367 |
| 446 | 52.9 | 30.2 | 22.7 | 360 |
| 435 | 53.2 | 30.7 | 22.5 | 366 |
| | | | | 365.0 |

Scale 50$^{\text{cm}}$.5 behind knife-edge, with blotting-paper arrangement, etc., as above. Statical flexure; 25.62 div.=.001 inch.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 17.3 | 24.8 | | |
| | 16.7 | 24.9 | | |
| | 16.9 | 25.3 | | |
| | 16.6 | 24.7 | | |
| | 16.4 | 24.6 | div. | μ |
| | 15.8 | 24.3 | 8.28 | 234.4 |
| | 15.4 | 24.1 | | |
| | 15.3 | 23.9 | | |
| | 15.1 | 23.4 | | |
| | 14.7 | 23.0 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0478 | 19.2 | 5.0 | 14.2 | 210 |
| 469 | 18.8 | 5.2 | 13.6 | 205 |
| 460 | 18.8 | 5.4 | 13.4 | 206 |
| 447 | 18.7 | 6.0 | 12.7 | 201 |
| 439 | 18.6 | 5.8 | 12.8 | 207 |
| 434 | 18.4 | 5.7 | 12.7 | 207 |
| 428 | 17.8 | 5.3 | 12.5 | 207 |
| 418 | 18.5 | 5.2 | 12.3 | 208 |
| 409 | 16.7 | 5.0 | 11.7 | 202 |
| 400 | 16.3 | 4.8 | 11.5 | 204 |
| 394 | 16.2 | 4.7 | 11.5 | 207 |
| | | | | 205.9 |

### 1880, JANUARY 11.

Flexure in third position, about 52$^{\text{cm}}$.7 in front of knife-edge and 118$^{\text{cm}}$.5 below. All clamped. No weight on stand. Statical flexure. 84.4 div.=.01 inch.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 72.3 | 66.6 | | |
| | 72.8 | 66.3 | | |
| | 71.4 | 66.2 | div. | μ |
| | 71.5 | 65.6 | 5.87 | 506 |
| | 71.2 | 65.1 | | |
| | 71.0 | 65.1 | | |
| | 70.8 | 65.0 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| . 0484 | 62. 8 | 73. 3 | 10. 5 | 467 |
| 476 | 63. 9 | 74. 9 | 11. 0 | 498 |
| 470 | 64. 1 | 74. 7 | 10. 6 | 487 |
| 466 | 63. 3 | 73. 7 | 10. 4 | 481 |
| 461 | 63. 2 | 73. 7 | 10. 5 | 491 |
| 454 | 63. 8 | 74. 0 | 10. 2 | 485 |
| | | | | 484 |

All tight. Weight of 2,700g on top of stand; otherwise the same. 84.4 div. of scale=.01 inch Statical.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| . 001 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 84. 7 | . 0500 | 93. 6 | 87. 3 | | |
| 84. 3 | | 93. 0 | 86. 6 | | |
| 84. 2 | | 92. 5 | 86. 4 | div.<br>6. 26 | μ<br>540 |
| 84. 4 | | 92. 5 | 86. 3 | | |
| | | 92. 4 | 86. 1 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| . 0498 | 85. 2 | 98. 8 | 13. 6 | 588 |
| 474 | 86. 3 | 98. 0 | 11. 7 | 532 |
| 469 | 86. 0 | 98. 0 | 12. 0 | 552 |
| 462 | 86. 0 | 98. 0 | 12. 0 | 560 |
| 442 | 83. 0 | 94. 7 | 11. 7 | 571 |
| 419 | 86. 3 | 96. 8 | 10. 5 | 541 |
| 409 | 85. 3 | 95. 8 | 10. 5 | 554 |
| 401 | 85. 8 | 96. 0 | 10. 2 | 547 |
| | | | | 556 |

Hand-tightened above; otherwise the same. Statical.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| . 0500 | 75. 2 | 68. 7 | | |
| | 75. 0 | 68. 1 | | |
| | 75. 1 | 68. 0 | | |
| | 80. 1 | 73. 7 | div.<br>6. 79 | μ<br>585 |
| | 84. 1 | 77. 1 | | |
| | 84. 3 | 77. 4 | | |
| | 84. 4 | 77. 7 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| . 0424 | 25. 8 | 38. 7 | 12. 9 | 655 |
| 417 | 25. 4 | 38. 8 | 13. 4 | 692 |
| 413 | 25. 3 | 38. 6 | 13. 3 | 699 |
| 408 | 25. 3 | 38. 1 | 12. 8 | 677 |
| 400 | 25. 7 | 37. 0 | 11. 3 | 609 |
| 388 | 26. 3 | 37. 2 | 10. 9 | 606 |
| 379 | 26. 4 | 37. 9 | 11. 5 | 653 |
| | | | | 656 |

Statical flexure. Feet unclamped; otherwise same.

| | *Scale readings.* | | | |
|---|---|---|---|---|
| Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| .0500 | 48.1 | 41.7 | | |
| | 47.4 | 41.7 | div. | μ |
| | 47.4 | 41.5 | 6.02 | 519 |
| | 47.9 | 41.8 | | |
| | 47.7 | 41.7 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0414 | 38.2 | 49.6 | 11.4 | 593 |
| 405 | 38.2 | 48.9 | 10.7 | 569 |
| 398 | 37.7 | 48.6 | 10.9 | 590 |
| 389 | 38.6 | 48.7 | 10.1 | 560 |
| 377 | 38.6 | 48.9 | 10.3 | 588 |
| | | | | 580 |

Statical flexure, with blotting-paper under feet; otherwise same; 84.16 div.=.01 inch.

| | | *Scale readings.* | | | |
|---|---|---|---|---|---|
| .01 inch. | Arc. | Zero. | Out. | Mean diff. | $f_0$. |
| 84.4 | .0500 | 73.2 | 65.8 | | |
| 84.1 | | 72.9 | 66.2 | div. | μ |
| 84.2 | | 73.1 | 66.0 | 7.00 | 603 |
| 84.1 | | 73.3 | 66.1 | | |
| 84.0 | | 72.7 | 66.1 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0369 | 67.8 | 78.1 | 10.3 | 601 |
| 361 | 67.7 | 77.9 | 10.2 | 610 |
| 360 | 68.0 | 77.2 | 9.2 | 552 |
| 340 | 66.8 | 75.8 | 9.0 | 571 |
| 338 | 67.0 | 76.3 | 9.3 | 582 |
| 333 | 67.0 | 76.0 | 9.0 | 552 |
| 328 | 67.8 | 76.2 | 8.4 | |
| | | | | 583 |

## 1880, JANUARY 21.

Third position; about $53^{cm}$ in front of middle of knife-edge, and $120^{cm}$ below; 84.72 div. of scale=.01 inch. Statical flexure.

| .01 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 84.7 | .0500 | 81.9 | 88.7 | | |
| 84.3 | | 82.3 | 88.6 | div. | μ |
| 84.6 | | 82.0 | 88.4 | 6.38 | 546.4 |
| 85.0 | | 82.9 | 88.9 | | |
| 85.0 | | 82.4 | 88.8 | | |

Dynamical flexure; with same arrangement.

| | | | | μ |
|---|---|---|---|---|
| .0507 | 82.2 | 94.9 | 12.7 | 537 |
| 500 | 82.2 | 96.0 | 13.8 | 591 |
| 496 | 82.3 | 95.2 | 12.9 | 556 |
| 488 | 82.8 | 94.8 | 12.0 | 526 |
| 478 | 82.8 | 94.8 | 12.0 | 537 |
| 464 | 82.7 | 94.7 | 12.0 | 554 |
| | | | | 550.8 |

Same as above, except that a weight of 25 pounds is put on top of stand. Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 35.5 | 41.7 | | |
| | 35.9 | 41.8 | | |
| | 35.5 | 41.6 | div. | μ |
| | 34.8 | 41.3 | 6.15 | 526.9 |
| | 35.0 | 41.1 | | |
| | 34.9 | 41.0 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0488 | 34.8 | 47.1 | 12.3 | 539 |
| 481 | 35.2 | 46.8 | 11.6 | 516 |
| 476 | 35.0 | 46.8 | 11.8 | 531 |
| 468 | 35.0 | 46.9 | 11.9 | 544 |
| 459 | 34.3 | 45.8 | 11.5 | 537 |
| 439 | 35.0 | 45.4 | 10.4 | 507 |
| | | | | 529.5 |

1880, JANUARY 23.

Second position; $50^{cm}.8$ behind knife-edge. No weight on; 26.27 div. =.001 inch. Statical flexure.

| .003 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 78.9 | .0500 | 4.7 | 10.6 | | |
| 79.0 | | 3.0 | 7.2 | | |
| 78.7 | | 9.6 | 16.0 | | |
| 78.7 | | 24.7 | 32.0 | | |
| | | 25.1 | 31.8 | | |
| | | 26.5 | 33.7 | div. | μ |
| | | 6.0 | 12.4 | 6.23 | 172.1 |
| | | 11.0 | 17.9 | | |
| | | 13.2 | 19.0 | | |
| | | 1.3 | 6.8 | | |
| | | 21.3 | 27.9 | | |
| | | 22.4 | 28.3 | | |
| | | 28.3 | 34.3 | | |
| | | 25.1 | 30.9 | | |
| | | 23.2 | 30.0 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0329 | 12.7 | 19.1 | 6.4 | 134 |
| 399 | 12.4 | 19.4 | 7.0 | 121 |
| 304 | 18.4 | 24.7 | 6.3 | 143 |
| 298 | 17.1 | 24.3 | 7.2 | 166 |
| 259 | 23.6 | 29.8 | 6.2 | 165 |
| 389 | 23.8 | 33.7 | 9.9 | 175 |
| 338 | 23.4 | 32.3 | 8.9 | 181 |
| 319 | 27.3 | 35.4 | 8.1 | 175 |
| 294 | 2.5 | 9.4 | 6.9 | 162 |
| 289 | 3.2 | 9.2 | 6.0 | 143 |
| 278 | 4.2 | 10.4 | 6.2 | 154 |
| 276 | 3.5 | 10.2 | 6.7 | 168 |
| 265 | 3.9 | 10.0 | 6.1 | 159 |
| 259 | 5.2 | 11.3 | 6.1 | 162 |
| | | | | 157.6 |

The mean of the last swinging is $164^{\mu}.3$.

### 1880, JANUARY 25.

Second position; 25 pounds weight on stand. Tube lengthened; 27.44 div. of scale=.001 inch Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 8.4 | 2.3 | | |
| | 7.4 | 1.4 | | |
| | 8.3 | 1.7 | | |
| | 8.3 | 1.8 | div. | μ |
| | 7.2 | 0.1 | 6.57 | 173.8 |
| | 9.9 | 3.2 | | |
| | 9.6 | 3.2 | | |
| | 10.0 | 3.3 | | |
| | 11.3 | 4.5 | | |
| | 11.5 | 4.7 | | |

Dynamical flexure; with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0478 | 7.7 | 20.6 | 12.9 | $178^{\mu}$ |
| 467 | 8.8 | 20.8 | 12.0 | 170 |
| 455 | 9.4 | 20.9 | 11.5 | 167 |
| 439 | 10.4 | 21.2 | 10.8 | 163 |
| 432 | 10.2 | 21.2 | 11.0 | 169 |
| 422 | 10.2 | 20.7 | 10.5 | 165 |
| 416 | 10.3 | 20.6 | 10.3 | 164 |
| 392 | 11.8 | 21.5 | 9.7 | 163 |
| 384 | 12.0 | 22.2 | 10.2 | 176 |
| | | | | 168.3 |

Weight taken off; otherwise same. Statical flexure.

| .003 inch. | Arc. | Scale readings. | | Diff. | $f_7$. |
|---|---|---|---|---|---|
| 82.4 | .0500 | 14.1 | 7.3 | | |
| 82.8 | | 14.5 | 8.3 | | |
| 82.5 | | 15.2 | 8.7 | | |
| 82.3 | | 16.7 | 9.6 | div. | μ |
| 82.1 | | 17.0 | 10.4 | 6.59 | 174.3 |
| 82.2 | | 16.9 | 10.4 | | |
| 82.2 | | 23.4 | 16.7 | | |
| 82.1 | | 23.1 | 16.8 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_7$. |
|---|---|---|---|---|
| .0482 | 18.3 | 30.9 | 12.6 | $173^{\mu}$ |
| 474 | 19.2 | 31.6 | 12.4 | 173 |
| 461 | 18.3 | 30.6 | 12.3 | 176 |
| 457 | 18.3 | 29.8 | 11.5 | 167 |
| 450 | 20.0 | 31.7 | 11.7 | 172 |
| 444 | 19.8 | 31.1 | 11.3 | 168 |
| 437 | 20.2 | 31.2 | 11.0 | 167 |
| 424 | 21.0 | 31.6 | 10.6 | 165 |
| | | | | 170.3 |

First position: about $57^{cm}.0$ in front of knife-edge; 26.85 div. of scale=.001 inch. Statical. No weight on.

| Arc. | Scale readings. | | Diff. | |
|---|---|---|---|---|
| 0.500 | 15.5 | 3.4 | | |
| | 15.8 | 4.0 | div. | μ |
| | 16.5 | 4.5 | 12.07 | 326.3 |
| | 17.1 | 4.9 | | |
| | 17.8 | 5.5 | | |
| | 17.6 | 5.6 | | |

Dynamical flexure, with same arrangement.

| .003 inch. | | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|---|
| | | | | | | μ |
| 80.7 | 80.3 | .0481 | 11.3 | 34.2 | 22.9 | 322 |
| 80.5 | 80.6 | 473 | 11.3 | 33.8 | 22.5 | 322 |
| 80.8 | 80.9 | 467 | 12.0 | 34.0 | 22.0 | 318 |
| 80.1 | 80.6 | 459 | 11.8 | 34.0 | 22.2 | 327 |
| | | 448 | 12.2 | 33.9 | 21.7 | 327 |
| | | 441 | 13.3 | 34.4 | 21.1 | 324 |
| | | 437 | 13.4 | 34.2 | 20.8 | 322 |
| | | | | | | 322.9 |

Weight on stand. Statical flexure. Otherwise same.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 20.0 | 32.3 | | |
| | 21.8 | 34.1 | div. | μ |
| | 22.5 | 34.6 | 12.17 | 329.0 |
| | 22.7 | 35.1 | | |
| | 23.4 | 35.4 | | |
| | 23.7 | 35.6 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0483 | 10.8 | 34.1 | 23.3 | 326 |
| 467 | 11.3 | 33.8 | 22.5 | 326 |
| 458 | 10.9 | 32.4 | 21.5 | 317 |
| 446 | 11.7 | 33.3 | 21.6 | 327 |
| 438 | 11.7 | 32.7 | 21.0 | 324 |
| 429 | 12.7 | 33.6 | 20.9 | 329 |
| 419 | 12.6 | 32.7 | 20.1 | 324 |
| 406 | 13.0 | 32.4 | 19.4 | 323 |
| | | | | 324.6 |

Summary of dynamical and statical observations, with pendulum on Repsold stand, made at York.

*All tight; no load.*

| | | Statical. | Dynamical. |
|---|---|---|---|
| $56^{cm}.6$ forward, | $f_0$ | $326^{\mu}.4$ | $323^{\mu}.5$ |
| $50^{cm}.5$ back, | $f_0$ | $172^{\mu}.4$ | $150^{\mu}.6$ |
| $52^{cm}.7$ forward, $118^{cm}.5$ below, | $f_0$ | $504^{\mu}.4$ | $482^{\mu}.9$ |
| Inclination of axis to knife-edge, | | 42°.9 | 49°.0 |
| Distance of axis from middle of knife-edge, | | $1^{m}.159$ | $1^{m}.086$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.114$ | $2^{\mu}.137$ |
| | $F_0$ | $245^{\mu}.0$ | $232^{\mu}.2$ |

*The same arrangement.*

| | | Statical. | Dynamical. |
|---|---|---|---|
| $57^{cm}.0$ forward, | $f_0$ | $326^{\mu}.3$ | $322^{\mu}.9$ |
| $50^{cm}.8$ back, | $f_0$ | $173^{\mu}.2$ | $167^{\mu}.3$ |
| $53^{cm}.0$ forward, $120^{cm}$ below, | $f_0$ | $546^{\mu}.4$ | $550^{\mu}.8$ |
| Inclination of axis to knife-edge, | | 37°.0 | 36°.5 |
| Distance of axis from middle of knife-edge, | | $1^{m}.040$ | $0^{m}.993$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.359$ | $2^{\mu}.424$ |
| | $F_0$ | $245^{\mu}.3$ | $240^{\mu}.6$ |

*All tight; load of* $2^{k}.7$.

| | | Statical. | Dynamical. |
|---|---|---|---|
| $56^{cm}.6$ forward, | $f_0$ | $332^{\mu}.7$ | $329^{\mu}.1$ |
| $50^{cm}.5$ back, | $f_0$ | $164^{\mu}.9$ | $148^{\mu}.1$ |
| $52^{cm}.7$ forward, $118^{cm}.5$ below, | $f_0$ | $539^{\mu}.6$ | $556^{\mu}.0$ |
| Inclination of axis to knife-edge, | | 41°.1 | 40°.6 |
| Distance of axis from middle of knife-edge, | | $1^{m}.023$ | $0^{m}.899$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.385$ | $2^{\mu}.597$ |
| | $F_0$ | $244^{\mu}.0$ | $233^{\mu}.4$ |

*All tight; load of* $11^{k}.3$.

| | | | |
|---|---|---|---|
| $57^{cm}.0$ forward, | $f_0$ | $329^{\mu}.0$ | $324^{\mu}.6$ |
| $50^{cm}.8$ back, | $f_0$ | $173^{\mu}.8$ | $168^{\mu}.3$ |
| $53^{cm}.0$ forward, $120^{cm}$ below, | $f_0$ | $526^{\mu}.9$ | $529^{\mu}.4$ |
| Inclination of axis to knife-edge, | | 40°.3 | 39°.5 |
| Distance of axis from middle of knife-edge, | | $1^{m}.009$ | $1^{m}.063$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.226$ | $2^{\mu}.277$ |
| | $F_0$ | $246^{\mu}.9$ | $242^{\mu}.0$ |

*Front taps above hand-tightened.*

| | | | |
|---|---|---|---|
| $56^{cm}.6$ forward, | $f_0$ | $406^{\mu}.0$ | $397^{\mu}.4$ |
| $50^{cm}.5$ back, | $f_0$ | $121^{\mu}.7$ | $^{\mu}.1$ |
| $52^{cm}.7$ forward, $118^{cm}.5$ below, | $f_0$ | $584^{\mu}.9$ | $656^{\mu}.0$ |
| Inclination of axis to knife-edge, | | 58°.9 | 50°.3 |
| Distance of axis from middle of knife-edge, | | $0^{m}.850$ | $0^{m}.681$ |
| $f_0$ at 1 cm. from axis, | | $3^{\mu}.099$ | $3^{\mu}.559$ |
| | $F_0$ | $255^{\mu}.7$ | $242^{\mu}.4$ |

*Tight above; binding-screws of front feet loose.*

| | | | |
|---|---|---|---|
| $56^{cm}.6$ forward, | $f_0$ | $344^{\mu}.6$ | $344^{\mu}.3$ |
| $50^{cm}.5$ back, | $f_0$ | $193^{\mu}.0$ | $177^{\mu}.1$ |
| $52^{cm}.7$ forward, $118^{cm}.5$ below, | $f_0$ | $518^{\mu}.9$ | $580^{\mu}.3$ |
| Inclination of axis to knife-edge, | | 43°.0 | 37°.4 |
| Distance of axis from middle of knife-edge, | | $1^{m}.273$ | $0^{m}.995$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.077$ | $2^{\mu}.572$ |
| | $F_0$ | $264^{\mu}.5$ | $255^{\mu}.9$ |

*All tight; blotting-paper under the feet.*

| | | | |
|---|---|---|---|
| $56^{cm}.6$ forward, | $f_0$ | $379^{\mu}.6$ | $365^{\mu}.0$ |
| $50^{cm}.5$ back, | $f_0$ | $234^{\mu}.4$ | $205^{\mu}.9$ |
| $52^{cm}.7$ forward, $118^{cm}.5$ below, | $f_0$ | $603^{\mu}.4$ | $580^{\mu}.1$ |
| Inclination of axis to knife-edge, | | 35 .0 | 38°.7 |
| Distance of axis from middle of knife edge, | | $1^{m}.282$ | $1^{m}.179$ |
| $f_0$ at 1 cm. from axis, | | $2^{\mu}.362$ | $2^{\mu}.384$ |
| | $F_0$ | $302^{\mu}.9$ | $281^{\mu}.0$ |

These measures are interesting as showing that while the dynamical flexure at the point of application of the force is constantly less than the statical, yet the angular flexure is less in the statical experiments than in the dynamical ones. This fact probably indicates the cause of the difference between the two kinds of flexure, namely, that in the dynamical experiments the flexure-wave has not had time to fully reach the distant parts of the apparatus.

### 1880, MARCH 17.

Top of Repsold stand fastened to an oak plank, which is bolted to top of Geneva tripod. Statical observations with weight ($1^k$) and pulley; 76.3 div. of scale=.003 inch. Scale $56^{cm}.8$ in front of middle of knife-edge.

| *Scale readings.* | | | |
|---|---|---|---|
| Wt. on. | Wt. off. | Mean diff. | $f_0$. |
| 4.0 | 29.0 | | |
| 2.3 | 26.7 | div. | μ |
| 3.9 | 28.3 | 24.62 | 154.7 |
| 1.6 | 26.2 | | |
| 3.4 | 28.1 | | |

Scale $50^{cm}.5$ behind knife-edge; 76.7 div.=.003 inch.

| Wt. on. | Wt. off. | Mean diff. | $f_0$. |
|---|---|---|---|
| 6.1 | 0.3 | | |
| 1.9 | 6.7 | | |
| 21.3 | 25.3 | div. | μ |
| 25.7 | 29.8 | 4.42 | 28.9 |
| 23.0 | 27.6 | | |
| 21.2 | 25.8 | | |

### 1880, APRIL 5.

Experiments on oak plank support as last used. (It has been removed and put on again since last experiment.) Statical flexure; with weight and pulley. Scale about $50^{cm}.0$ behind knife-edge. Filar micrometer, 1 revolution=$100^{\mu}$.

| *Micrometer readings.* | | | |
|---|---|---|---|
| Wt. on. | Wt. off. | Diff. | $f_0$. |
| | | ρ | |
| 4.186 | 4.150 | 0.036 | |
| .218 | .180 | .038 | |
| .242 | .216 | .026 | |
| .291 | .256 | .035 | |
| 4.425 | 4.390 | .035 | μ |
| .451 | .415 | .036 | 21.9 |
| .484 | .452 | .032 | |
| .523 | .492 | .031 | |
| 4.566 | 4.528 | .038 | |
| .595 | .562 | .033 | |
| .625 | .591 | .034 | |
| .650 | .611 | .039 | |
| | | .035 | |

Scale about $56^{cm}.7$ in front of knife-edge; otherwise the same.

| Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|
| 3.200 | 3.022 | 0.178 | |
| 4.427 | 4.247 | .180 | |
| .405 | .216 | .189 | |
| .385 | .215 | .170 | |
| .368 | .205 | .163 | μ |
| .345 | .175 | .170 | 109.1 |
| .269 | .092 | .177 | |
| .231 | .064 | .167 | |
| .236 | .178 | .178 | |
| .236 | .165 | .165 | |
| .221 | .178 | .178 | |
| .210 | .177 | .177 | |
| .203 | .157 | .157 | |
| | | 0.173 | |

Scale about 44$^{cm}$ in front, and about 120$^{cm}$ below the middle point of knife-edge; otherwise same as before. The flexure is now in the reverse direction from the pull.

*Micrometer readings.*

| Wt. on. | Wt. off. | Diff. | $f_0$. |
|---|---|---|---|
| 3.735 | 3.308 | $0.^{\rho}427$ | |
| .760 | .597 | .163 | |
| .622 | .424 | .198 | |
| .808 | .343 | .465 | |
| 4.121 | .624 | .497 | |
| 3.740 | .270 | .470 | |
| .448 | .160 | .288 | |
| .926 | .277 | .649 | |
| .676 | .189 | .487 | |
| .759 | .386 | .373 | |
| .660 | .480 | .180 | |
| .585 | .378 | .207 | $229.^{\mu}6$ |
| 4.785 | 4.550 | .235 | |
| 5.913 | 5.668 | .245 | |
| .873 | .384 | .489 | |
| .639 | .545 | .094 | |
| .438 | .186 | .252 | |
| .306 | 4.567 | .739 | |
| .073 | .910 | .163 | |
| .037 | .831 | .206 | |
| .066 | .661 | .405 | |
| .112 | .640 | .472 | |
| .113 | .652 | .461 | |
| 4.943 | .714 | .229 | |
| 5.158 | .607 | .551 | |
| .103 | .756 | .347 | |
| .187 | .646 | .541 | |
| | | 0.364 | |

## 1880, APRIL 17.

Repsold stand supported on oak blocks, six inches high, and braced together. Microscope as in former experiments. Scale 56$^{cm}$.7 in front of middle of knife-edge; 21.93 div. of scale=.001 inch. Statical flexure with pendulum.

| .004 inch. | | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|---|
| 87.7 | 87.5 | .0500 | 5.7 | 24.0 | | |
| 87.1 | 87.9 | | 22.6 | 40.9 | | |
| 86.8 | 88.3 | | 18.9 | 37.9 | | |
| 87.6 | 87.7 | | 10.9 | 30.9 | | |
| 87.9 | 88.0 | | 3.5 | 21.7 | div. | $\mu$ |
| 87.6 | | | 2.2 | 20.3 | 18.72 | 619.6 |
| 88.0 | | | 21.8 | 41.2 | | |
| 87.9 | | | 17.3 | 36.1 | | |
| | | | 15.0 | 32.6 | | |
| | | | 6.5 | 25.2 | | |
| | | | 4.9 | 23.7 | | |
| | | | 17.8 | 37.2 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| ′ | | | | μ |
| .0494 | 42.7 | 9.6 | 33.1 | 554 |
| 490 | 41.8 | 7.5 | 34.3 | 579 |
| 484 | 40.7 | 7.0 | 33.7 | 576 |
| 454 | 32.3 | 2.8 | 29.5 | 538 |
| 448 | 32.7 | 3.6 | 29.1 | 538 |
| 438 | 32.4 | 3.3 | 29.1 | 549 |
| 433 | 30.1 | 1.2 | 28.9 | 552 |
| | | | | 556 |

Scale $50^{\mathrm{cm}}.4$ behind knife-edge. Otherwise same. Statical.

| | | | | |
|---|---|---|---|---|
| .0500 | 22.3 | 31.7 | | |
| | 3.8 | 13.4 | | |
| | 5.3 | 14.6 | | |
| | 5.4 | 14.0 | | |
| | 10.0 | 18.5 | div. | μ |
| | 11.0 | 20.3 | 9.11 | 301.5 |
| | 18.3 | 26.0 | | |
| | 20.0 | 28.9 | | |
| | 22.5 | 31.4 | | |
| | 3.4 | 12.2 | | |
| | 4.7 | 14.4 | | |
| | 8.1 | 17.8 | | |
| | 10.0 | 19.5 | | |
| | 11.0 | 20.6 | | |

Dynamical flexure, with same arrangement.

| | | | | |
|---|---|---|---|---|
| | | | | μ |
| .0489 | 28.4 | 9.6 | 18.8 | 318 |
| 484 | 27.7 | 8.9 | 18.8 | 321 |
| 477 | 26.2 | 7.8 | 18.4 | 319 |
| 470 | 24.8 | 6.9 | 17.9 | 296 |
| 465 | 23.7 | 6.7 | 17.0 | 303 |
| | | | | 315 |

### 1880, April 18.

Repsold stand raised up on pieces of rubber 2¼ inches thick. Scale $50^{\mathrm{cm}}.3$ behind knife-edge; $21^{\mathrm{div}}.94$ of scale=.001 inch. Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 13.8 | 42.1 | | |
| | 16.4 | 39.3 rej. | | |
| | 19.8 | 48.7 | | |
| | 20.9 | 48.6 | div. | μ |
| | 23.7 | 51.8 | 28.36 | 939.2 |
| | 20.9 | 49.7 | | |
| | 23.1 | 51.6 | | |
| | 26.0 | 54.2 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. μ |
|---|---|---|---|---|
| .0460 | *49.6 | 2.4 | 47.2 | 849 |
| 452 | 49.6 | 2.8 | 46.8 | 856 |
| 447 | 49.3 | 3.9 | 45.4 | 840 |
| 438 | 48.7 | 4.6 | 44.1 | 833 |
| 426 | 49.2 | 5.3 | 43.9 | 853 |
| | | | | 846 |

$57^{cm}.0$ in front of knife-edge; 21.9 div. of scale=.001 inch. Statical flexure.

| | | | | |
|---|---|---|---|---|
| .0500 | 36.8 | 2.8 | | |
| | 52.0 | 17.5 | | |
| | 48.6 | 15.7 | | |
| | 45.6 | 11.9 | | |
| | 43.5 | 12.3 | div. | μ |
| | 41.8 | 8.3 | 33.2 | 1099 |
| | 40.8 | 6.7 | | |
| | 38.6 | 6.5 | | |
| | 37.2 | 5.1 | | |
| | 36.3 | 2.5 | | |
| | 35.4 | 1.9 | | |

Dynamical flexure, with same arrangement.

| .004 inch. | | Arc. | Scale readings. | | Diff. | $f_0$. μ |
|---|---|---|---|---|---|---|
| 88.0 | 87.7 | .0509 | 75.8 | 14.0 | 61.8 | 1008 |
| 88.4 | 87.6 | 498 | 71.8 | 12.7 | 59.1 | 985 |
| 87.9 | 87.3 | 487 | 70.3 | 12.4 | 57.9 | 987 |
| 88.3 | 87.2 | 482 | 68.4 | 11.3 | 57.1 | 984 |
| 88.1 | 87.3 | 473 | 66.8 | 10.0 | 56.8 | 997 |
| | | 467 | 66.8 | 11.0 | 55.8 | 992 |
| | | 458 | 64.4 | 11.2 | 53.2 | 964 |
| | | | | | | 989 |

Third position; 81.1div. of scale=0.1 inch. Statical flexure.

| | | | | |
|---|---|---|---|---|
| .0500 | 19.0 | 26.3 | | |
| | 18.2 | 26.3 | div. | μ |
| | 18.7 | 26.0 | 7.9 | 709.8 |
| | 18.3 | 27.1 | | |
| | 18.3 | 26.5 | | |

Dynamical flexure, with same arrangement.

| .01 inch. | Arc. | Scale readings. | | Diff. | $f_0$. μ |
|---|---|---|---|---|---|
| 81.2 | .0320 | 15.8 | 23.6 | 7.8 | 545 |
| 80.9 | 304 | 15.8 | 22.8 | 7.0 | 514 |
| 81.2 | 288 | 15.3 | 22.3 | 7.0 | 543 |
| | 278 | 15.1 | 22.2 | 7.1 | 570 |
| | 270 | 15.2 | 21.8 | 6.6 | 545 |
| | 262 | 15.2 | 21.6 | 6.4 | 545 |
| | | | | | 543 |

---

* The first figure in this column is everywhere recorded as 5; the observer, however, notes that it should be 4.

1880, April 21.

Flexure observed again on rubber feet. Scale 50$^{cm}$.2 behind knife-edge; 22.17 div. of scale = .001 inch. Statical flexure.

| .004 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 88.6 | .0500 | 15.6 | 38.9 | | |
| 88.8 | | 13.2 | 37.8 | | |
| 88.8 | | 13.8 | 38.8 | | |
| 88.6 | | 18.8 | 43.5 | | μ |
| | | 21.0 | 44.5 | 24.5 | 803.8 |
| | | 19.7 | 43.7 | | |
| | | 19.3 | 44.9 | | |
| | | 18.9 | 43.9 | | |
| | | 19.8 | 43.8 | | |
| | | 19.2 | 44.1 | | |

Dynamical flexure, with same arrangement.

| | | | | μ |
|---|---|---|---|---|
| .0472 | 45.8 | 5.2 | 40.6 | 707 |
| 463 | 48.7 | 8.4 | 40.3 | 715 |
| 456 | 48.7 | 9.5 | 39.2 | 707 |
| 450 | 48.7 | 9.4 | 39.3 | 718 |
| 443 | 48.0 | 9.4 | 38.6 | 716 |
| | | | | 713 |

57$^{cm}$.1 in front of knife-edge; 21.99 div. of scale = .001 inch. Statical flexure.

| .004 inch. | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|
| 88.7 | .0500 | 47.9 | 18.7 | | |
| 88.6 | | 50.0 | 20.0 | | |
| 87.6 | | 48.8 | 18.2 | | |
| 88.3 | | 48.0 | 18.3 | | |
| 87.5 | | 46.3 | 16.6 | | |
| 87.8 | | 44.0 | 12.8 | div. | μ |
| 87.9 | | 43.0 | 11.1 | 30.1 | 989.5 |
| 88.0 | | 41.2 | 12.4 | | |
| 88.0 | | 38.7 | 7.9 | | |
| 88.0 | | 35.5 | 6.2 | | |
| | | 31.2 | 2.8 | | |
| | | 33.7 | 2.4 | | |
| | | 31.1 | 0.6 | | |

Dynamical flexure, with same arrangement.

| | | | | μ |
|---|---|---|---|---|
| .0495 | 61.7 | 6.3 | 55.4 | 921 |
| 488 | 61.2 | 6.8 | 54.4 | 918 |
| 480 | 58.7 | 5.3 | 53.4 | 915 |
| 476 | 59.4 | 6.2 | 53.2 | 920 |
| 467 | 56.7 | 4.0 | 52.7 | 928 |
| 459 | 55.8 | 4.0 | 51.8 | 929 |
| | | | | 922 |

Block feet again. Scale $56^{cm}.9$ forward of middle of knife-edge; 22.19 div. of scale=.001 inch Statical flexure first.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 22.5 | 11.3 | | |
| | 28.5 | 17.3 | | |
| | 31.2 | 20.2 | div. | μ |
| | 12.3 | 1.1 | 11.14 | 365.2 |
| | 14.9 | 3.6 | | |
| | 14.7 | 3.9 | | |
| | 13.8 | 2.5 | | |
| | 13.6 | 2.5 | | |

Dynamical flexure, with same.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0459 | 30.5 | 10.2 | 20.3 | 362 |
| 450 | 36.8 | 17.3 | 19.5 | 355 |
| 445 | 37.2 | 17.7 | 19.5 | 359 |
| 439 | 35.8 | 16.4 | 19.4 | 362 |
| 430 | 36.0 | 16.7 | 19.3 | 368 |
| 420 | 33.7 | 15.4 | 18.3 | 358 |
| 414 | 34.0 | 16.2 | 17.8 | 353 |
| | | | | 360 |

Scale $50^{cm}.1$ behind middle point of knife-edge; 22.08 div. of scale=.001 inch. Statical.

| 0.004 inch. | | Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|---|---|
| 88.7 | 88.7 | .0500 | 21.1 | 31.0 | | |
| 88.2 | 88.8 | | 18.6 | 28.8 | | |
| 88.7 | 88.8 | | 17.7 | 27.2 | div. | μ |
| 87.9 | | | 16.5 | 26.4 | 10.10 | 331.2 |
| 88.2 | | | 13.3 | 23.9 | | |
| 88.2 | | | 12.4 | 22.5 | | |
| | | | 11.3 | 21.8 | | |

Another set.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 12.4 | 23.6 | | |
| | 11.4 | 22.4 | div. | μ |
| | 10.6 | 21.3 | 10.8 | 354.1 |
| | 11.5 | 21.8 | | |
| | 11.5 | 22.3 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0495 | 31.3 | 8.0 | 8.3 | 386 |
| 489 | 31.0 | 7.4 | 23.6 | 396 |
| 483 | 29.7 | 7.3 | 23.4 | 380 |
| 478 | 29.6 | 6.8 | 22.8 | 391 |
| 469 | 28.8 | 6.4 | 22.4 | 392 |
| 467 | 28.7 | 6.8 | 21.9 | 385 |
| | | | | 388 |

Scale $56^{cm}.9$ again in front of knife-edge; 22 div. of scale=.001 inch. Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 35.9 | 23.9 | | |
| | 18.7 | 8.3 | div. | μ |
| | 27.7 | 18.3 | 10.8 | 354.1 |
| | 31.0 | 19.8 | | |
| | 31.7 | 20.7 | | |

Dynamical flexure, with same.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | $\mu$ |
| .0484 | 31.9 | 11.7 | 20.2 | 342 |
| 476 | 33.6 | 13.8 | 19.8 | 341 |
| 469 | 34.3 | 14.8 | 19.5 | 341 |
| 460 | 36.0 | 16.8 | 19.2 | 342 |
| 456 | 36.8 | 17.6 | 19.2 | 345 |
| | | | | 342 |

## 1880, April 25.

Observations on *wooden stand.* Much troubled by tremor, probably due in great measure to the irregular heating of the wooden blocks by the illuminating flame. Third position=$55^{cm}$ in front of knife-edge and $118^{cm}$ below; 71.72 div. of scale=.01 inch. Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 32.8 | 36.5 rej. | | |
| | 25.0 | 30.3 | | |
| | 24.8 | 30.2 | | |
| | 32.3 | 37.4 | | |
| | 32.4 | 37.2 | | |
| | 32.6 | 38.0 | | |
| | 32.3 | 37.8 | div. | $\mu$ |
| | 35.2 | 41.1 | 5.52 | 558.6 |
| | 35.0 | 41.0 | | |
| | 36.4 | 41.6 | | |
| | 34.4 | 42.1 rej. | | |
| | 36.6 | 42.3 | | |
| | 36.2 | 42.4 | | |
| | 37.0 | 42.5 | | |
| | 36.7 | 42.3 | | |
| | 36.8 | 42.5 | | |
| | 37.0 | 42.8 | | |
| | 36.6 | 41.4 | | |
| | 36.9 | 42.2 | | |
| | 36.9 | 43.0 | | |

Dynamical flexure, with same arrangement.

| | | | | |
|---|---|---|---|---|
| | | | | $\mu$ |
| .0478 | 32.3 | 42.2 | 9.9 | 524 |
| 469 | 32.0 | 41.8 | 9.8 | 529 |
| 453 | 30.3 | 40.1 | 9.8 | 546 |
| 442 | 30.1 | 40.1 | 10.0 | 572 |
| 438 | 31.2 | 42.1 | 10.9 | 630 |
| 437 | 31.9 | 41.9 | 10.0 | 579 |
| 433 | 31.1 | 41.0 | 9.9 | 579 |
| 426 | 31.8 | 42.0 | 10.2 | 605 |
| 419 | 31.8 | 41.2 | 9.4 | 567 |
| 416 | 32.2 | 41.2 | 9.0 | 546 |
| 413 | 32.3 | 41.4 | 9.1 | 557 |
| 412 | 32.2 | 41.3 | 9.1 | 559 |
| 409 | 32.7 | 42.1 | 9.4 | 582 |
| 403 | 33.3 | 42.2 | 8.9 | 559 |
| 400 | 33.3 | 42.3 | 9.0 | 569 |
| | | | | 567 |

Scale in front of knife-edge about 56$^{cm}$.8 (not measured). Statical flexure; 21.67 div. of scale= .001 inch.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 30.0 | 16.8 | | |
| | 25.7 | 12.6 | | |
| | 25.4 | 12.4 | | |
| | 27.2 | 13.7 | | |
| | 27.7 | 14.1 | | |
| | 30.0 | 16.6 | div. | μ |
| | 32.1 | 18.4 | 13.4 | 448.7 |
| | 33.3 | 20.1 | | |
| | 27.4 | 13.4 | | |
| | 31.4 | 18.8 | | |
| | 32.4 | 19.7 | | |
| | 56.4 | 43.2 | | |
| | 56.7 | 41.9 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0480 | 55.4 | 32.3 | 23.1 | 403 |
| 459 | 57.7 | 35.8 | 21.9 | 399 |
| 451 | 58.7 | 38.8 | 19.9 | 369 |
| 443 | 59.3 | 38.4 | 20.9 | 395 |
| 425 | 59.3 | 39.6 | 19.7 | 388 |
| 416 | 60.7 | 41.2 | 19.5 | 393 |
| 399 | 63.7 | 45.8 | 17.9 | 376 |
| | | | | 389 |

Scale 50$^{cm}$.4 behind knife-edge. Statical flexure.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| .0500 | 22.8 | 15.8 | | |
| | 24.7 | 18.2 | | |
| | 36.7 | 29.8 | | |
| | 52.8 | 29.2 | | |
| | 16.3 | 47.4 | | |
| | 22.7 | 10.8 | div. | μ |
| | 23.6 | 17.2 | 6.49 | 217.0 |
| | 27.6 | 17.0 | | |
| | 27.4 | 21.0 | | |
| | 31.4 | 25.3 | | |
| | 36.0 | 29.3 | | |
| | 41.0 | 33.3 | | |
| | 43.4 | 36.8 | | |

Dynamical flexure, with same arrangement.

| Arc. | Scale readings. | | Diff. | $f_0$. |
|---|---|---|---|---|
| | | | | μ |
| .0495 | 46.3 | 30.6 | 15.7 | 265 |
| 488 | 47.7 | 31.4 | 16.3 | 280 |
| 483 | 49.3 | 33.7 | 15.6 | 270 |
| 478 | 50.3 | 34.4 | 15.9 | 279 |
| 469 | 51.3 | 36.3 | 15.0 | 268 |
| 463 | 52.8 | 37.3 | 15.5 | 280 |
| 426 | 52.8 | 38.5 | 14.3 | 281 |
| 414 | 53.4 | 41.3 | 12.1 | 244 |
| 410 | 54.9 | 41.0 | 13.9 | 284 |
| 407 | 56.0 | 43.0 | 13.0 | 267 |
| | | | | 272 |

The above experiments of April, 1880, were made with a view of testing experimentally the question of whether the statical or dynamical flexures should be used in reducing the periods of oscillation, or whether some intermediate value would be preferable. The pendulum was actually swung upon all these supports. Unfortunately, the measures of flexure of the excessively flexible supports are extremely discordant.

*Repsold support on rubber blocks.*

| | $f_0$ forward. | | $f_0$ behind. | | $f_0$ below. | | $F_0$. | $F_0$ |
|---|---|---|---|---|---|---|---|---|
| | Statical. | Dynamical. | Statical. | Dynamical. | Statical. | Dynamical. | Statical. | Dynamical. |
| | $\mu$ | $\mu$ | $\mu$ | $\mu$ | $\mu$ | $\mu$ | $\mu$ | $\mu$ |
| April 18, | 1099 | 989 | 939 | 846 | 710 | 543 | 1014 | 913 |
| April 21, | 989 | 922 | 804 | 713 | | | 891 | 811 |

From the circumstances of the experiment, the results of the second day are to be absolutely preferred. The pendulum was swung on this support on April 18 and 20. The measurements of the flexure of the Repsold tripod on an oaken support are still more utterly discordant. The second experiment of April 21 seems to be the best, and this gives $F_0=354^\mu$ for the statical flexure, and the dynamical flexure appears to be very little less. For the stiffest support we have $F_0=62^\mu 9$. statical; dynamical not measured.

The details of the experiments to determine the periods of oscillation on these supports will be given in another report. The following are the results:

*Stiffest support.*

(Method of transits.)

| | Heavy end down. | Heavy end up. |
|---|---|---|
| | s. | s. |
| March 31, | 1. 006435 | 1. 006473 |
| April 2, | 439 | 478 |
| April 4, | 434 | 483 |
| April 4, | 444 | 475 |
| Mean, | 1. 006438 | 1. 006477 |

(Method of eye and ear coincidences.)

| | | |
|---|---|---|
| March 26, | 1. 006443 | 1. 006468 |
| March 27, | 447 | 475 |
| March 28, | 437 | 467 |
| March 29, | 435 | 460 |
| Mean, | 1. 006440 | 1. 006470 |

*Repsold support.*

(Method of transits.)

| | Heavy end down. | Heavy end up. |
|---|---|---|
| | s. | s. |
| April 7, | 1. 006499 | 1. 006506 |
| April 30, | 491 | 485 |
| May 2, | 500 | 528 |
| May 3, | 500 | 516 |
| Mean, | 1. 006498 | 1. 006509 |

### *Repsold support.*

(Method of eye and ear coincidences.)

| | Heavy end down. s. | Heavy end up. s. |
|---|---|---|
| March 19, | 1. 006523 | 1. 006523 |
| March 21, | 490 | 473 |
| March 22, | 508 | 527 |
| March 23, | 492 | 533 |
| June 4, | 495 | 505 |
| June 5, | 489 | 483 |
| June 6, | 507 | 511 |
| June 6, | 515 | 505 |
| Mean, | 1. 006502 | 1. 006508 |

### *Oaken support.*

(Method of eye and ear coincidences.)

| | Heavy end down. s. | Heavy end up. s. |
|---|---|---|
| April 24, | 1. 006545 | 1. 006530 |
| April 25, | 542 | 526 |
| April 27, | 536 | 521 |
| April 28, | 538 | 539 |
| Mean, | 1. 006540 | 1. 006529 |

### *On India-rubber blocks.*

| | | |
|---|---|---|
| April 18, | 1. 006706 | 1. 006612 |
| April 20, | 703 | 610 |
| Mean, | 1. 006705 | 1. 006611 |

Let us now try the dynamical correction of these periods. For the Repsold support the dynamical $F_0=237^\mu$; thence we deduce the corrections for the other supports, as follows:

| | Heavy end down. s. | Heavy end up. s. |
|---|---|---|
| Period, Repsold support, | 1. 006500 | 1. 006509 |
| Dynamic correction, | −84 | −36 |
| Corrected period, | 1. 006416 | 1. 006473 |
| Period, stiffest support, | 1. 006439 | 1. 006475 |
| Period, oaken support, | 1. 006540 | 1. 006529 |
| Period, on India rubber, | 1. 006705 | 1. 006611 |
| Apparent corrections: | | |
| Stiffest support, | 23 | 2 |
| Oaken support, | 124 | 56 |
| India rubber, | 289 | 138 |

The values of $F_0$, calculated from these corrections, are as follows:

| | $\mu$ | $\mu$ |
|---|---|---|
| Stiffest support, | 65 | 13 |
| Oaken support, | 352 | 371 |
| India rubber, | 821 | 915 |

Of course, extremely little weight is to be attached to the values calculated from "heavy end up." For the stiffest support and the oaken support the result is in very good accord with the statically observed flexure. For the India rubber support the dynamically observed flexure seems to be indicated, or rather something between this and the results of statical measures.

### *General conclusions.*

1. The flexibility of almost any pendulum support has an important effect on the time of oscillation, and should be measured.

2. The flexure rotates the knife-edge about an axis, sometimes not over 60 cm. distant. It is, therefore, altogether erroneous to measure the flexure at any other point than the middle of the knife-edge, unless it be measured at a number of points and reduced to that point.

3. On a properly constructed support the difference between the statical and dynamical flexure should be immaterial. The dynamical flexure is less than the statical, owing to the time required for the transmission of the wave of strain to the more distant parts of the apparatus. The true correction seems to be intermediate between that calculated from the statical and the dynamical flexures, but pretty decidedly nearer to the latter.

4. A support like the Repsold tripod will grow more flexible with time, owing probably to the slight loosening of some parts.

5. Any dirt, cement, or other elastic film under the feet of such a tripod may greatly increase the flexure, as well as the difference between the two kinds.

6. If the flexure is considerable, it is likely to vary from day to day, or even during the course of an experiment.

7. The tightening of the parts may or may not greatly affect the flexure.

8. The loading of the support has no sensible effect.

9. Experiments made with weight and pulley give a larger value for the flexure than those made with the pendulum drawn to one side.

### NOTE ON HARDY'S NODDY.

The theory of Hardy's noddy is very simple. When two pendulums oscillate on the same support in parallel planes, I have shown (Am. Jour. Sci., third series, xviii, 113) that one of the differential equations is

$$\lambda\, \mathrm{D}_t^2 \varphi + \mathrm{D}_t^2 s = -\gamma \varphi,$$

where

$t$ is the time;

$\varphi$, the instantaneous angle of inclination of one pendulum;

$s$, the instantaneous linear displacement of its knife-edge from the position of repose;

$\lambda$, the virtual length of the pendulum;

$\gamma$, the vertical acceleration of each particle, or the constant of force of restoration of the pendulum.

The Hardy's noddy is a pendulum placed on the support of another pendulum so as to oscillate in a parallel plane. Its natural period $\tau = \circledcirc \sqrt{\frac{\lambda}{\gamma}}$ is as nearly as possible equal to T, the period of the main pendulum; but $\gamma$, instead of being gravity, is the excess of the force of a spring over gravity and is made to be as small as possible, $\lambda$ being correspondingly small, so as to give $\tau$ the right value. The noddy being very light, the value and changes of $s$ are determined entirely by the main pendulum. We may, therefore, write

$$s = \mathrm{S} \cos \frac{t}{\mathrm{T}} \circledcirc$$

Substituting this value in the differential equation, the solution of the latter is

$$\varphi = \Phi \cos \frac{t - t_0}{\tau} \circledcirc - \frac{1}{\gamma} \frac{\mathrm{S} \circledcirc^2}{\tau^2 - \mathrm{T}^2} \cos \frac{t}{\mathrm{T}} \circledcirc.$$

But the noddy has no oscillation to begin with. This fact is represented by the equations

$$t_0 = 0 \qquad \Phi = \frac{1}{\gamma} \cdot \frac{\mathrm{S} \circledcirc^2}{\tau^2 - \mathrm{T}^2}$$

We thus have

$$\varphi=\frac{1}{\gamma}\cdot\frac{S\copyright^2}{\tau^2-T^2}\left(\cos\frac{t}{\tau}\copyright-\cos\frac{t}{T}\copyright\right)=\frac{2}{\gamma}\cdot\frac{S^2\copyright^2}{\tau^2-T^2}\cdot\sin\frac{\tau-T}{2\tau T}t\copyright\cdot\sin\frac{\tau+T}{2\tau T}t\copyright.$$

This equation shows that the noddy oscillates with a period that is a sort of mean between its natural period and that of the large pendulum. The amplitude of oscillation increases from nothing at an initial rate equal to

$$\frac{S\copyright^3}{\gamma(\tau+T)\tau T};$$

a rate not much affected by the value of $(\tau-T)$. But the amplitude increases more and more slowly, and reaches its maximum when

$$t=\frac{\tau T}{\tau-T},$$

after which it again diminishes and after the lapse of an equal time vanishes. At the beginning, the phase of motion of the support is $\frac{1}{2}\copyright$, and that of the noddy is 0, so that the support is one quadrant ahead. At the time of the first maximum the phase of the support is

$$\left(\tfrac{1}{2}+\frac{\tau}{\tau-T}\right)\copyright$$

and that of the noddy is

$$\frac{1}{2}\frac{\tau+T}{\tau-T}\copyright.$$

Subtracting the second from the first we see that the two motions are in opposition. When the motion of the noddy vanishes its phase is a quadrant in advance of that of the support. The motion immediately recommences, but

$$\sin\frac{\tau-T}{2\tau T}t\copyright$$

is now negative, and this shows that the difference of phase changes to the opposite quadrant, and that the two oscillations again proceed toward opposition.

We have thus far not taken account of the resistance to the motion of the noddy, although this must evidently be large. In consequence of it, the natural motion of the noddy would be of the form

$$\varphi=\Phi\circlearrowleft^{-\frac{t}{\theta}\copyright}\cos\frac{t}{\tau}\copyright.$$

From this we easily infer that the differential equation is

$$D_t^2\,\varphi+2\frac{\copyright}{\theta}D_t\,\varphi+\frac{\copyright^2}{\tau^2}\,\varphi=\frac{S}{\lambda}\,\frac{\copyright^2}{T^2}\cos\frac{t}{T}\copyright.$$

The solution of this is

$$\varphi=\frac{S}{\lambda}\,\frac{1}{\dfrac{4\tau^2T^2}{\theta^2(\tau^2-T^2)}+\dfrac{\tau^2-T^2}{\tau^2}}\left(\circlearrowleft^{-\frac{t}{\theta}\copyright}\cos\frac{t}{\tau}\copyright-\cos\frac{t}{T}\copyright\right)+\frac{S}{\lambda}\,\frac{\dfrac{2\tau^2T}{\theta(\tau^2-T^2)}}{\dfrac{4\tau^2T^2}{\theta^2(\tau^2-T^2)}+\dfrac{\tau^2-T^2}{\tau^2}}\sin\frac{t}{T}\copyright.$$

The signification of this is that the noddy approaches indefinitely toward settling down to an oscillation strictly synchronous with that of the support. Its ultimate amplitude is very little less than half what the maximum amplitude would be without resistance. But the phase may differ very much from that of the motion of the support. Namely, if the noddy is in precise adjustment to the period of the large pendulum, its phase will be one quadrant behind that of the support. If the noddy naturally oscillates slower than the large pendulum, its phase may be anywhere from one quadrant in arrear to opposition; if the noddy naturally oscillates faster than the pendulum, it may be anywhere from one quadrant behind, to coincidence.

If, then, $\gamma$ is one tenth of gravity, $\tau^2-T^2$ one thousandth of a second, and S one tenth of a micron, the amplitude of movement of the noddy will be one thousandth of the radius, a quantity easily measured with a microscope.

## ON THE INFLUENCE OF THE FLEXIBILITY OF THE SUPPORT ON THE OSCILLATION OF A PENDULUM.

(Translated from French into English by the author.)

NEW YORK, *July* 13, 1877.

DEAR SIR: On taking charge of the Coast Survey researches upon gravity, I ordered of Messrs. Repsold a reversible pendulum, to be a copy of that of the Prussian Geodetical Institute. But the instrument makers were at that time so taken up with the construction of instruments for the Transit of Venus, that the pendulum was only ready in the spring of 1875. I then went to Hamburg to receive it; and from Hamburg I went on to Berlin, where I found General Baeyer rather dissatisfied with the results obtained with the Prussian instrument. He specially mentioned the flexibility of the tripod, a source of error which pendulum experimenters have surely never overlooked. The pendulum apparatus that I had carried with me from America having been ruined in transportation, I was under the necessity of employing the new instrument, and therefore undertook to measure and take account of the error in question.

A pendulum support might be rickety, so that the pendulum in its oscillations should throw the knife-edge plane from one position to another, without its undergoing any resistance to the motion other than inertia and friction, between two fixed points. This, however, does not happen in the case of any of the supports that I have examined; for, upon observing their behavior under a high-power microscope, I have always found that they spring back exactly to their original position after every flexure that I have applied to them. In short, the movement with which we have to do is the oscillatory flexure of an elastic body. The amplitude of the oscillation is, at most, about $\frac{1}{5000}$ of that of the lower knife-edge of the pendulum, so that its square may be neglected.

The plane of support of the knife is itself undoubtedly bent during the movement; but I neglect this and limit myself to the consideration of the movement of its middle point. When to this middle point is applied a horizontal force perpendicular to the knife edge, the latter describes a movement of revolution around an axis which, in the case of the Repsold apparatus, is situated behind and above the tripod at a distance of about a meter from the knife-edge. We can neglect the difference between this movement and a translation, until we come to measure its amount. There is also a minute variation in the vertical pressure of the pendulum on the support, but this is very far from producing any sensible effect on the period of oscillation.

Let us denote by

$m$ the mass of a particle,
$r$ its distance from the knife-edge,
$\omega$ the inclination, at rest, to the vertical of the perpendicular let fall from the particle on to the knife-edge,
M the mass of the pendulum,
$l$ the length of the corresponding simple pendulum,
$h$ the distance of the center of mass from the knife-edge,
T the period of the oscillation,
$g$ the acceleration of gravity,
$\varepsilon$ the elasticity of the support,
$\varphi$ the instantaneous inclination of the pendulum to its position of rest,
$s$ the instantaneous displacement of the middle point of the knife-edge from its position of rest,
$t$ the time.

Then, the horizontal velocity of a particle will be

$$r\cos(\varphi+\omega)\,\mathrm{D}_t\varphi+\mathrm{D}_t s$$

and its vertical velocity will be

$$r\sin(\varphi+\omega)\,\mathrm{D}_t\varphi.$$

Its living force will, therefore, be

$$\frac{1}{2}mr^2\,(\mathrm{D}_t\varphi)^2+mr\cos\,(\varphi+\omega)\,\mathrm{D}_t\varphi.\,\mathrm{D}_ts+\frac{1}{2}m\,(\mathrm{D}_ts)^2,$$

and that of the pendulum will be

$$\frac{1}{2}\mathrm{M}lh\,(\mathrm{D}_t\varphi)^2+\mathrm{M}h\cos\varphi.\,\mathrm{D}_t\varphi.\,\mathrm{D}_ts+\frac{1}{2}\mathrm{M}\,(\mathrm{D}_ts)^2.$$

The living force of the motion of the support itself may be left out of account since it involves the square of an excessively small velocity.[*]

The differential of the potential energy is

$$\mathrm{M}gh\sin\varphi.\,d\varphi+\varepsilon s.\,ds.$$

There is really a third term to be added to this expression dependent on the molecular friction of the matter of the support. But I think we may neglect this term; for its effect cannot be very great, and its coëfficient is, at any rate, unknown.[†]

From the expressions for the living force and potential we deduce the Lagrangian equations

$$l\mathrm{D}_t^2\varphi+\cos\varphi.\,\mathrm{D}_t^2s=-g\sin\varphi$$

$$-h\sin\varphi.\,(\mathrm{D}_t\varphi)^2+h\cos\varphi.\,\mathrm{D}_t^2\varphi+\mathrm{D}_t^2s=-\frac{\varepsilon}{\mathrm{M}}s,$$

or, neglecting terms of the second degree,

$$l\mathrm{D}_t^2\varphi+\mathrm{D}_t^2s=-g\varphi$$

$$h\mathrm{D}_t^2\varphi+\mathrm{D}_t^2s=-\frac{\varepsilon}{\mathrm{M}}s.$$

[NOTE.—1882, July 24. I omit the solution of these equations as originally given, and substitute the following, which is perhaps less inelegant. Subtracting the second equation from the first, we get

$$(l-h)\mathrm{D}_t^2\varphi+g\varphi=\frac{\varepsilon}{\mathrm{M}}s$$

or

$$\mathrm{D}_t^2s=\frac{\mathrm{M}}{\varepsilon}(l-h)\mathrm{D}_t^4\varphi+\frac{\mathrm{M}g}{\varepsilon}\mathrm{D}_t^2\varphi$$

Substituting this value in the first differential equation, we have

$$\frac{\mathrm{M}}{\varepsilon}(l-h)\,\mathrm{D}_t^4\varphi+\left(l+\frac{\mathrm{M}g}{\varepsilon}\right)\mathrm{D}_t^2\varphi+g\varphi=0.$$

Separating the operator into factors, and using the abbreviation

$$i=4\frac{\mathrm{M}g}{\varepsilon l}\cdot\frac{1-\frac{h}{l}}{\left(1+\frac{\mathrm{M}g}{\varepsilon l}\right)^2}$$

we get

$$\left[\mathrm{D}_t^2+\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1+\sqrt{1-i})\right]\cdot\left[\mathrm{D}_t^2+\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1-\sqrt{1-i})\right]\varphi=0.$$

---

[*] It is easy to see that the effect of this would be to increase the last term of the living force; this would affect the second of the differential equations just as if M had been multiplied and $h$ divided by the same quantity. But this would not affect the final result. [1882.]

[†] This is the point to which the greatest objection to my work has been made. [1882.]

The solution of this is

$$\varphi=\mathrm{A}_1 \cos\left(\sqrt{\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1-\sqrt{1-i})}\,.\,t+\eta_1\right)+\mathrm{A}_2 \cos\left(\sqrt{\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1+\sqrt{1-i})}\,.\,t+\eta_2\right)$$

where $\mathrm{A}_1$, $\mathrm{A}_2$, $\eta_1$, $\eta_2$ are arbitrary constants. On neglecting the square of $\frac{\mathrm{M}g}{\varepsilon l}$, this reduces to

$$\varphi=\mathrm{A}_1 \cos\left(\sqrt{\frac{g}{l}\left(1-\frac{\mathrm{M}g}{\varepsilon l}\right)}\,.\,t+\eta_1\right)+\mathrm{A}_2 \cos\left(\sqrt{\frac{\varepsilon}{\mathrm{M}}\cdot\frac{1+\frac{\mathrm{M}gh}{\varepsilon l^2}}{1-\frac{h}{l}}}\,.\,t+\eta_2\right)$$

The second term represents a mere tremor, for its period is very short, owing to the large value of $\varepsilon$. The period of the first harmonic constituent is

$$\mathrm{T}=\sqrt{\frac{l}{g}+\frac{\mathrm{M}}{\varepsilon}}$$

From the value of $\varphi$ and the first equation of this note, we deduce the following value of $s$:

$$s=\frac{\mathrm{M}g}{2\varepsilon}\left(-\frac{\varepsilon l}{\mathrm{M}g}(1-\sqrt{1-i})+1+\sqrt{1-i}\right)\mathrm{A}_1 \cos\left(\sqrt{\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1-\sqrt{1-i})}\,.\,t+\eta_1\right)$$

$$+\frac{\mathrm{M}g}{2\varepsilon}\left(-\frac{\varepsilon l}{\mathrm{M}g}(1+\sqrt{1-i})+1-\sqrt{1-i}\right)\mathrm{A}_2 \cos\left(\sqrt{\frac{\varepsilon l+\mathrm{M}g}{2\mathrm{M}(l-h)}(1+\sqrt{1-i})}\,.\,t+\eta_2\right)$$

It thus appears that the amplitude of the principal constituent of $s$ is nearly

$$h\frac{\mathrm{M}g}{\varepsilon l}\mathrm{A}_1,$$

while that of the other constituent is nearly $-l\mathrm{A}_2$.

To find the best way of starting the pendulum so as to make the ratio of $\mathrm{A}_2$ to $\mathrm{A}_1$ as small as possible, we must consider how to make the initial value of $s$ as nearly as possible $h\frac{\mathrm{M}g}{\varepsilon l}$ times the initial value of $\varphi$. Now, it is easy to see that if the pendulum is supported at a point at a distance $x$ from the knife-edge, any yielding of the support will diminish the value of $\varphi$ as expressed by the equation

$$ds=-x \sec \varphi.\, d\varphi.$$

Substituting this in the expression for the differential of the potential energy, this last becomes

$$\mathrm{M}gh \sin \varphi.\, d\varphi-\varepsilon s\, x \sec \varphi.\, d\varphi.$$

Equating this to zero, we find

$$s=h\frac{\mathrm{M}g}{\varepsilon x} \sin \varphi.\, \cos \varphi.$$

In order that this should be equal to $h\frac{\mathrm{M}g}{\varepsilon l}\varphi$, it is only necessary to put $x=l$, so that in starting the pendulum the finger or trigger should be applied at the lower knife-edge or center of gyration.]

The elasticity, $\varepsilon$, may be measured by observing the deflection, S, of the support produced by a horizontal force equal to the unit of weight. For

$$\varepsilon=\frac{g}{\mathrm{S}}$$

Substituting this value, we find

$$\varphi=\frac{A}{h}\cos\left(\sqrt{\frac{g}{\left(l+MS\frac{h}{l}\right)}}\,t\right)$$

Accordingly, the effect on the pendulum is to give it a virtual length greater than what it would have on a rigid support by $MS\frac{h}{l}$.

Let us denote the duration of an oscillation by T, and let $\varDelta$ be used to indicate the effects of flexure. Then, since

$$T^2=\varpi^2\frac{l}{g}$$

we have

$$\varDelta T^2=\frac{\varpi^2}{g}MS\frac{h}{l}.$$

If we distinguish by subjacent letters the two positions of a reversible pendulum, we have

$$\frac{\varpi^2 l}{g}=\frac{T_d^2 h_d-T_u^2 h_u}{h_d-h_u}$$

and

$$\varDelta l=MS,$$

or putting λ for the length of the second's pendulum

$$\varDelta\lambda=MS\frac{\lambda}{l}.$$

To determine the flexure, I fasten in the slot in the plane of suspension of the Repsold apparatus a fish-line passing horizontally in the direction of the pendulum's movement over an Atwood's machine pulley, and on the end of this cord I hang a kilogramme. [With a stronger support, the pendulum itself may conveniently replace the kilogramme.] On the extremity of the plane of suspension, or at the end of an arm attached thereto,* I stick a glass stage micrometer, turned so as to measure in a direction parallel to the impressed force. This scale is looked at by a microscope carrying a filar micrometer, and solidly mounted upon an independent support, the standard of which is a piece of gas pipe about 10 centimeters in diameter.

I now give a brief *résumé* of my results, beginning with the experiments to determine the position of the fixed axis about which the head of the Repsold support rotates during flexure.

### A.—*Experiments made on a level with the suspension plane.*

HOBOKEN, *March* 10, 1877. Temperature 13° C.

+ = forward; − = back.

| Distance of scale from end of plane. | Flexure in revolutions of the micrometer screw. | |
|---|---|---|
| | Observed. | Calculated. |
| *m.* | | |
| −0.496 | +0.211 | +0.209 |
| +0.053 | +.0356 | +0.358 |
| +0.318 | +0.436 | +0.431 |

The calculated quantities suppose that the axis pierces the suspension plane at a distance of $1^m.355$ behind the forward end of the suspension plane.

---

* This arm is best made of brass tubing, which may be cut out to make it lighter. [1882.]

### B.—*Experiments in the vertical of the forward end.*

HOBOKEN, *March* 12, 1877. Temperature 14° C. Observer, Sub-assistant SMITH.

+ = below; − = above.

| Position of the scale relative to the suspension plane. | Flexure in revolutions of the micrometer screw. | |
|---|---|---|
| | Observed. | Calculated. |
| *m.* | | |
| −0.44 | +0.196 | +0.196 |
| 0.000 | +0.340 | +0.332 |
| +0.395 | +0.446 | +0.454 |

The calculated quantities suppose the axis to pierce the vertical of the forward end of the suspension plane $1^m.07$ above this plane. It is not at all surprising that the instantaneous axis is above the suspension plane. Let us suppose that the flexure existed exclusively in three feet of the support. In this case the movement of the upper end of each foot would be perpendicular to the general direction of the foot, and at the same time perpendicular to the radius of the circle of revolution, so that the foot would be directed directly towards the fixed axis. The axis is without doubt behind the support, on account of the flexure of the plane itself.

I made experiments at Geneva, Paris, Berlin, and New York, in order to determine S numerically. The experiment at Geneva, made the 13th of September, was only a trial. But I had a good pulley which I had borrowed from the workshop of the Geneva society for the construction of physical instruments, and I got as an approximate value—

$$S=0^{mm}.034$$

The pulley that I used at Paris had considerable friction, to which can be attributed the fact that the numbers found differ sensibly from those obtained with the aid of better apparatus.

These are the figures—

January 18, 1876, at Messrs. Brünner, Temp. 1° C $S=0^{mm}.0363$
March 7, 1876, at the Paris Observatory, Temp. 9° C $S=0^{mm}.0371$

At Berlin I used a very delicate pulley which turned on friction-whels, in order to diminish the friction. It belonged to the Physical Cabinet of the Institute of Technology of Berlin, and was put at my disposition by the kindness of Professor Paalzow. The micrometric readings were made alternately with and without the weight, making but one reading each time, in order to avoid any error arising from the support of the micrometer, this being made of wood. In the readings made alternately with and without the weight, I ended with the arrangement with which I began (11 for one, and 10 for the other), in order that the mean instant of the observations should be the same for the two arrangements. The value of 1 division of the micrometer screw was measured separately.

Below are the results of the different series—

| | |
|---|---|
| May 24, 1876, a. m., | $S=0^{mm}.0340$ |
| Temp. 13° C., p. m., | $0^{mm}.0339$ |
| | $0^{mm}.0340$ |
| | $0^{mm}.0341$ |
| May 25, 1876, Temp. 13°, | $0^{mm}.0337$ |
| | $0^{mm}.0336$ |
| Mean, | $S=0^{mm}.0339\pm0^{mm}.001$ |

At Hoboken (near New York) I obtained, through the kindness of Professor Morton, an excellent pulley, made in the workshop of the Stevens Institute of Technology. I always made a reading on each one of the lines of the scale before changing the disposition of the weight.

The results of the separate series are—

| | |
|---|---|
| March 7, 1877, Temp. 15° C., | $S=0^{mm}.0342$ |
| March 10, 1877, Temp. 12°. | $0^{mm}.0332$ |
| | $0^{mm}.0337$ |
| | $0^{mm}.0343$ |
| | $0^{mm}.0342$ |
| | $0^{mm}.0339$ |
| | $0^{mm}.0334$ |
| These two series should have double weight in the reduction, | $0^{mm}.0342$<br>$0^{mm}.0342$ |
| Mean, | $S=0^{mm}.0340\pm 0^{mm}.0001$ |

In all the experiments made in the different positions of the scale the flexure obtained has been reduced to the center of the knife, and this last is what is called S.

It is to this last value that I give the preference.

It follows, from the experiments described on pages 430–431, made to determine the position of the axis of rotation, that the forward end of the suspension plane is distant from that axis by $\sqrt{1^{m}.355\times 1^{m}.07}=1^{m}.20$. And, since the movement of this end with the weight of a kilogramme is $S+0^{mm}.0008$, the correction $+0.0008$ arising from the reduction from the center of knife to the forward end, it follows that the torsion of the support by that force is $\frac{0^{mm}.0348}{1^{m}.20}=0.0000290=5.''8$. Although there is nothing to be suspected in this result, I wished to check it by a direct experiment. I attached a mirror at the extremity of the suspension plane, and, with the aid of a telescope, I measured the torsion by the reflection of a scale, and I found it 6″. This method, of course, is not as exact as the other.

In order to arrive at another confirmation of the theory, I made the following observations on the flexure produced by the oscillation of the pendulum itself in its two positions, using a tolerably high-power microscope (*i. e.*, magnifying 500 diameters). The scale used was made by Mr. Rodgers, of Harvard College Observatory. It is divided with extreme exactness, the interval between two lines being $\frac{1}{4000}$ of an English inch. It was fixed 70 millimeters before the center of the knife, which gives a correction to S of +.0019.

If $\Phi$ is the amplitude of oscillation on each side of the vertical, the double amplitude of the vibration of the scale should be

$$2\ M\ (S+0^{mm}.0019)\frac{h}{l}\Phi$$

in which $M=6.308$ and $\frac{h}{l}=\frac{17}{56}$ or $\frac{39}{56}$ according as the pendulum is suspended by the knife nearest or farthest from the center of gravity. I used this formula in calculating the quantities now given.

### DYNAMICAL FLEXURE.

A.—*Pendulum suspended by the knife farthest from the center of gravity.*

HOBOKEN, *March* 20, 1877.

| Φ | Amplitude of the movement of the scale. 1 div. = $\frac{1}{4000}$ inch. | |
|---|---|---|
| | Observed. | Calculated. |
| ° ′ | *Divisions.* | *Divisions.* |
| 2 32 | 2.2 | 2.2 |
| 2 30 | 2.1 | 2.1 |
| 2 24 | 2.0 | 2.1 |
| 2 22 | 1.9 | 2.0 |
| 2 20 | 1.9 | 2.0 |
| 2 19 | 1.95 | 2.0 |
| 1 43 | 1.5 | 1.5 |
| 0 47 | 0.8 | 0.7 |

B.—*Pendulum suspended by the knife nearest the center of gravity.*

| $\Phi$ | Amplitude of the movement of the scale. 1 div. $=\frac{1}{1000}$ in. | |
|---|---|---|
| | Observed. | Calculated. |
| ° ′ | *Divisions.* | *Divisions.* |
| 2 39 | 1.0 | 1.0 |
| 2 34 | 0.9 | 1.0 |
| 2 29 | 0.9 | 0.9 |
| 2 25 | 0.9 | 0.9 |
| 2 22 | 0.8 | 0.9 |
| 2 14 | 0.8 | 0.8 |
| 2 12 | 0.8 | 0.8 |
| 2 06 | 0.7 | 0.8 |
| 2 04 | 0.75 | 0.8 |
| 1 57 | 0.75 | 0.7 |
| 1 51 | 0.75 | 0.7 |

In making these observations, I saw distinctly the little subsidiary vibration at the end of each oscillation arising from the second term of the formula.

Finally, I swung the pendulum on two supports of different flexibility—one was the metallic tripod, by Repsold, to which refer the flexure measurements given above; the other was made by fixing the upper part of the Repsold tripod to a thick wooden plank by means of bronze bolts passing through the three holes through which the feet pass. These holes are conical, and the bolts fit exactly. I put on each bolt between the head of the support and the plank a leaden washer, so that, in tightening the bolts and compressing the washers, great stability was obtained and at the same time a horizontal position. The plank (which was 5 centimeters thick) was cut in order to make a place for the pendulum, and it was placed by force between a stone wall and a brick pillar. A slit was then cut, in which a pulley of an Atwood machine was placed to measure the flexure.

*Experiments on the flexure of this support.*

HOBOKEN, *May* 21, 1877.

| Distance of scale before +, behind − of the center of knife in English inches. | Distance of scale to suspension plane in English inches + above, − below. | Flexure in millimeters under a weight 1 kilogramme. | Temperature C. | Observer. |
|---|---|---|---|---|
| *Inches.* | *Inches.* | *mm.* | ° | |
| + 1.2 | − 1.3 | +0.0052 | 18.3 | E S. |
| + 1.2 | − 1.3 | + .0052 | 18.9 | E S. |
| + 1.2 | +39.5 | − .0425 | 20.0 | C. S. P. |
| +13.2 | +39.5 | − .0367 | | C. S. P. |

It follows that for this apparatus $S^1=0^{mm}.0031$, and that the difference between the values of S for the two supports is $0^{mm}.0309$. Now I find $\frac{\pi^2 l}{g}=1.0125$ sidereal seconds and $l=1^m$. Hence, we conclude that the difference of $\frac{\pi^2 l}{g}$ according as the pendulum oscillates on one or the other supports must be equal to

$$\frac{\pi^2 l}{g}\cdot\frac{M\,(S-S^1)}{l}=\frac{81}{80}\times 6.308\times 0.0309=0.000197$$

I swung the pendulum three times on the less solid support and once on the most solid to verify the theory. I observed 10 consecutive passages of the pendulum across the vertical at intervals of 5 minutes, using a relay that I invented for this purpose.

### A.—*Oscillations on the Repsold metallic support.*

HOBOKEN, *April* 1, 1877.

PENDULUM SUSPENDED BY THE KNIFE NEAREST THE CENTER OF GRAVITY.

| Number of oscillations. | Interval by chronometer. | Reduction to infinitely small arc. | Corrected interval. | Period. |
|---|---|---|---|---|
| | s. | s. | s. | s. |
| 300 | 301. 9652 | —0. 0130 | 301. 9522 | 1. 006507 |
| 296 | 297. 9408 | —0. 0084 | 297. 9324 | 528 |
| 298 | 299. 9533 | —0. 0060 | 299. 9473 | 535 |
| * Mean | | | | 1. 0065238 |

PENDULUM SUSPENDED BY THE KNIFE FARTHEST FROM THE CENTER OF GRAVITY.

| | | | | |
|---|---|---|---|---|
| | s. | s. | s. | s. |
| 296 | 297. 9094 | —0. 0092 | 297. 9002 | 1. 006420 |
| 302 | 303. 9374 | —0. 0081 | 303. 9295 | 389 |
| 296 | 297. 9060 | —0. 0066 | 297. 8994 | 417 |
| Mean | | | | 1. 0064067 |

Hence, we have

$$\mathrm{T}_1^2 = 1^{\mathrm{s}}.0128544$$
$$\mathrm{T}_2^2 = 1^{\mathrm{s}}.0130902$$

And since $h_1 : h_2 = 101 : 44$ we have

$$\frac{\pi^2 l}{g} = \frac{\mathrm{T}_1^2 h_1 - \mathrm{T}_2^2 h_2}{h_1 - h_2} = 1.013\left(1 - \frac{101 \times 0.0001456 + 44 \times 0.0000902}{57}\right) = 1.012672$$

This value is to be corrected for rate of chronometer and temperature. The chronometer lost $0^{\mathrm{s}}.86$ per day, which gives a correction to $\mathrm{T}^2$ of $+0^{\mathrm{s}}.000020$. The temperature during the time the heaviest mass was above was 12°.7 in the mean, and 12°.9 when this mass was below. Hence, to reduce to 13° we must apply a correction of

$$\frac{0.1 \times 101 - 0.3 \times 44}{57} = 0.0000186 = -0.000001$$

Hence we conclude

$$\frac{\pi^2 l}{g} \text{ at } 13^\circ \text{ C.} = 1.012691$$

*April* 7, 1877.

PENDULUM SUSPENDED BY THE KNIFE FARTHEST FROM THE CENTER OF GRAVITY.

| Number of oscillations. | Interval by chronometer. | Reduction to infinitely small arc. | Corrected interval. | Period. |
|---|---|---|---|---|
| | s. | s. | s. | s. |
| 290 | 291. 8794 | —0. 0103 | 291. 8691 | 1. 006445 |
| 296 | 297. 9131 | —0. 0086 | 297. 9045 | 434 |
| 298 | 299. 9241 | —0. 0073 | 299. 9168 | 432 |
| 298 | 299. 9241 | —0. 0060 | 299. 9181 | 437 |
| 358 | 360. 3090 | —0. 0058 | 360. 3032 | 434 |
| Mean | | | | 1. 0064357 |

PENDULUM SUSPENDED BY THE KNIFE NEAREST THE CENTER OF GRAVITY.

| | | | | |
|---|---|---|---|---|
| | s. | s. | s. | s. |
| 288 | 289. 9026 | —0. 0132 | 289. 8894 | 1. 006560 |
| 298 | 299. 9648 | —0. 0092 | 299. 9556 | 562 |
| 300 | 301. 9760 | —0. 0067 | 301. 9693 | 564 |
| 298 | 299. 9564 | —0. 0051 | 299. 9513 | 548 |
| 298 | 299. 9591 | —0. 0037 | 299. 9524 | 552 |
| Mean | | | | 1. 0065578 |

---

* When we have a series of equal consecutive intervals if $n$ is the number of intervals and $i$ is the position of one of them we should, in taking the mean, give to this interval the weight $-i\ (i-1)$.

Hence we have

$$T^2_1=1^s.0129128$$
$$T^2_2=1^s.0131586$$

$$\frac{\pi^2 l}{g}=1^s.012723$$

Daily correction, $+0^s.44$ $\qquad + \ .000010$

Temp. 15°.8 (both positions) $\qquad - \ .000052$

$$\frac{\pi^2 l}{g}\text{ at } 13^\circ \text{ C.}= \ 1.012681$$

*April* 8, 1877.

PENDULUM SUSPENDED BY THE KNIFE NEAREST THE CENTER OF GRAVITY.

| Number of oscillations. | Interval by chronometer. | Reduction to infinitely small arc. | Corrected time. | Period. |
|---|---|---|---|---|
| | *s.* | *s.* | *s.* | *s.* |
| 298 | 299. 9647 | −0. 0175 | 299. 9472 | 1. 006534 |
| 298 | 299. 9549 | −0. 0111 | 299. 9438 | 523 |
| 298 | 299. 9539 | −0. 0080 | 299. 9459 | 530 |
| 298 | 299. 9484 | −0. 0055 | 299. 9429 | 520 |
| 298 | 299. 9481 | −0. 0039 | 299. 9442 | 526 |
| Mean | | | | 1. 0065261 |

PENDULUM SUSPENDED BY KNIFE FARTHEST FROM CENTER OF GRAVITY.

| | | | | |
|---|---|---|---|---|
| | *s.* | *s.* | *s.* | *s.* |
| 298 | 299. 9229 | −0. 0066 | 299. 9163 | 1. 006431 |
| 298 | 299. 9213 | −0. 0058 | 299. 9155 | 426 |
| 297 | 298. 9125 | −0. 0049 | 298. 9076 | 423 |
| 299 | 300. 9236 | −0. 0042 | 300. 9194 | 419 |
| 298 | 299. 9174 | −0. 0035 | 299. 9136 | 422 |
| Mean | | | | 1. 0064246 |

$$\begin{aligned} & \quad s. \\ T_1^2 &= 1.0128905 \\ T_2^2 &= 1.0130948 \\ \frac{\pi^2 l}{g} &= 1.012733 \end{aligned}$$

Daily correction, $-0^s.41$ $\qquad - \ .000009$

Temp. heavy end up, 13°.2 $\Big\}$ $- \ .000016$
Temp. heavy end down, 13°.5

$$\frac{\pi^2 l}{g}\text{ at } 13^\circ=1.012708$$

Hence the three experiments on the Repsold support give for the value of $\frac{\pi^2 l}{g}$ at 13° C.

*s.*
April 1, 1.012691
April 7, 1.012681
April 8, 1.012708

Mean, 1.012693

### B.—*Experiments made on the stiffest support.*

HOBOKEN, *May* 14, 1877.

PENDULUM SUSPENDED BY THE KNIFE FARTHEST FROM THE CENTER OF GRAVITY.

| Mean instant of 10 transits. | | | Interval of 298 oscillations. | Reduction to infinitely small arc. | Corrected interval. | Interval of 298 oscillations. | Reduction to infinitely small arc. | Corrected interval. |
|---|---|---|---|---|---|---|---|---|
| *h.* | *m.* | *s.* | *s.* | *s.* | *s.* | *s.* | *s.* | *s.* |
| 14 | 6 | 22. 4307 | .......... | .......... | .......... | .......... | .......... | .......... |
| .. | 7 | 22. 8245 | .......... | .......... | .......... | .......... | .......... | .......... |
| .. | 11 | 22. 3337 | 299. 9030 | —0. 0132 | 299. 8898 | .......... | .......... | .......... |
| .. | 12 | 22. 7213 | .......... | .......... | .......... | 299. 8968 | —0. 0126 | 299. 8842 |
| .. | 16 | 22. 2313 | 299. 8976 | —0. 0110 | 299. 8866 | .......... | .......... | .......... |
| .. | 17 | 22. 6209 | .......... | .......... | .......... | 299. 8996 | —0. 0106 | 299. 8890 |
| .. | 22 | 22. 5145 | .......... | .......... | .......... | 299. 8936 | —0. 0087 | 299. 8849 |
| .. | 23 | 22. 9017 | .......... | .......... | .......... | .......... | .......... | .......... |
| .. | 27 | 22. 4055 | .......... | .......... | .......... | 299. 8910 | —0. 0074 | 299. 8836 |
| .. | 28 | 22. 7949 | 299. 8932 | —0. 0072 | 299. 8860 | .......... | .......... | .......... |
| .. | 33 | 22. 6896 | 299. 8947 | —0. 0060 | 299. 8887 | .......... | .......... | .......... |

PENDULUM SUSPENDED BY THE KNIFE NEAREST THE CENTER OF GRAVITY.

| Mean instant of 10 transits. | | | Intervals of 298 oscillations. | Reduction to infinitely small arc. | Corrected intervals. |
|---|---|---|---|---|---|
| *h.* | *m.* | *s.* | *s.* | *s.* | *s.* |
| 15 | 53 | 22. 4041 | .......... | .......... | .......... |
| .. | 58 | 22. 3579 | 299. 9538 | —0. 0198 | 299. 9340 |
| .. | 3 | 22. 3058 | 299. 9479 | —0. 0131 | 299. 9348 |
| .. | 8 | 22. 2531 | 299. 9473 | —0. 0087 | 299. 9386 |
| .. | 13 | 22. 2119 | 299. 9588 | —0. 0062 | 299. 9526 |
| .. | 18 | 22. 1554 | 299. 9435 | – 0. 0044 | 299. 9391 |
| .. | 23 | 22. 1011 | 299. 9457 | —0. 0031 | 299. 9426 |

$$\text{Mean } T_2 = 1^{s}.0065104.$$

Hence we find—

$$\begin{array}{lr}
 & s. \\
 & T_1^2 = 1.0127144 \\
 & T_2^2 = 1.0130632 \\
 & \frac{\pi^2 l}{g} = 1.012445 \\
\text{Daily corr. to chron. } + 2^{s}.59 & - \ .000060 \\
\left.\begin{array}{l}\text{Temp. heavy end down, } 14^{\circ}.18 \\ \text{Temp. heavy end up, } \quad 15^{\circ}.00\end{array}\right\} & - \ .000010 \\
\hline
 & \frac{\pi^2 l}{g} \text{ at } 13^{\circ} = 1.012495
\end{array}$$

Comparing this value with the one obtained with the other support we find a difference of 0.000198. The difference, according to the computations of the experiments on flexure, ought to have been 0.000197,* which shows a sufficient agreement.

Yours, most faithfully,

[Signed] C. S. PEIRCE,
*Assistant United States Coast Survey.*

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* In the original publication, owing to an erroneous value for the mass of the pendulum, this is erroneously calculated as 0.000191. The agreement of the experiments with theory is, therefore, much better than was supposed.

# ON THE INFLUENCE OF INTERNAL FRICTION UPON THE CORRECTION OF THE LENGTH OF THE SECONDS PENDULUM FOR THE FLEXIBILITY OF THE SUPPORT.

It has been shown by Prof. A. M. Mayer that the only sensible resistance to the motion of a tuning-fork is proportional to the velocity. In the case of a slowly vibrating body the chief effect is probably due to that lagging of the strain after the stress, which Weber has called the elastic after-effect (*Nachwirkung*). The influence of the former mode of resistance upon the period of oscillation of a pendulum oscillating on an elastic tripod is easily calculated. The same thing cannot, in my opinion, be effected for the other kind of resistance, in the present state of our knowledge; nevertheless, the main characteristics of the motion may be made out. Put

$t$, for the time;
$\varphi$, for the instantaneous angle of deflection of the pendulum;
$s$, for the instantaneous horizontal displacement of the knife-edge from its position of equilibrium, in consequence of the flexure of the support;
$l$, for the length of the corresponding simple pendulum;
$h$, for the distance from the knife-edge to the center of mass of the pendulum;
$g$, for the acceleration of gravity;
$\gamma$, for the ratio of $g$ to the statical displacement of the point of support, which would be produced by a horizontal force equal to the weight of the pendulum;
$a$, for the coefficient of internal friction supposed proportional to the velocity.

Then the differential equations are

$$\begin{aligned} l\mathrm{D}^2{}_t\varphi + \mathrm{D}^2{}_t s &= -g\varphi \\ h\mathrm{D}^2{}_t\varphi + \mathrm{D}^2{}_t s &= -\gamma s - a\mathrm{D}_t s \end{aligned}$$

The solution of these equations will be of the form (using $\circledcirc$ for the Neperian base and $\circledcirc$ for the ratio of circumference to diameter):

$$\left.\begin{aligned} \varphi &= \mathrm{A}_1\circledcirc^{z_1 t} + \mathrm{A}_2\circledcirc^{z_2 t} + \mathrm{A}_3\circledcirc^{z_3 t} + \mathrm{A}_4\circledcirc^{z_4 t} \\ s &= \mathrm{B}_1\circledcirc^{z_1 t} + \mathrm{B}_2\circledcirc^{z_2 t} + \mathrm{B}_3\circledcirc^{z_3 t} + \mathrm{B}_4\circledcirc^{z_4 t} \end{aligned}\right\} \quad (1)$$

where $z_1$, $z_2$, $z_3$, $z_4$ are the roots of the equation

$$(l-h)z^4 + alz^3 + (\gamma l + g)z^2 + agz + \gamma g = 0,$$

where, for each subscript letter,

$$\mathrm{B} = -(l + \frac{g}{z^2})\ \mathrm{A},$$

and where four arbitrary constants are determined by the initial conditions.

The roots of the biquadratic equation are all imaginary, and may be written

$$\begin{aligned} z_1 &= -\xi_1 + \eta_1\sqrt{-1} \qquad & z_3 &= -\xi_2 + \eta_2\sqrt{-1} \\ z_2 &= -\xi_1 - \eta_1\sqrt{-1} \qquad & z_4 &= -\xi_2 - \eta_2\sqrt{-1} \end{aligned}$$

Expressing the coefficients in terms of the real and imaginary parts of the roots, the equation becomes

$$\begin{aligned} &z^4 + 2(\xi_1 + \xi_2)z^3 + (4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 + \eta_1^2 + \eta_2^2)z^2 \\ &+ 2[(\xi_1^2 + \eta_1^2)\xi_2 + (\xi_2^2 + \eta_2^2)\xi_1]z + (\xi_1^2 + \eta_1^2)(\xi_2^2 + \eta_2^2) = 0. \end{aligned}$$

If the terms in $z^3$ and $z$ were neglected, that is, if $a$ were neglected, the solution of the false equation so obtained would be as follows (where observe the varying sign of $\eta_1$):

$$\begin{aligned} \text{False } z^2 = &-\tfrac{1}{2}(4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 + \eta_1^2 + \eta_2^2) \\ &\pm \tfrac{1}{2}(4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 - \eta_1^2 + \eta_2^2)\sqrt{1 + 4\frac{4\xi_1\xi_2\eta_1^2 - \xi_1^2(\eta_2^2 - \eta_1^2) - \xi_1^2\xi_2^2}{(4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 - \eta_1^2 + \eta_2^2)^2}} \end{aligned}$$

Now, in the actual case, $\eta_2$ will be at least 100 times $\eta_1$, $\xi_2$ will be quite large, and $\xi_1$ very small. We may, therefore, neglect the square of the fraction under the radical; and we have very closely

$$\text{False } z_1^2 = \text{false } z_2^2 = -\eta_1^2 + \frac{4\xi_1\xi_2\eta_1^2 - \xi_1^2(\eta_2^2-\eta_1^2) - \xi_1^2\xi_2^2}{4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 - \eta_1^2 + \eta_2^2}$$

$$\text{False } z_3^2 = \text{false } z_4^2 = -\eta_2^2 - \xi_1^2 - \xi_2^2 - 4\xi_1\xi_2 \frac{4\xi_1\xi_2\eta_1^2 - \xi_1^2(\eta_2^2-\eta_1^2) - \xi_1^2\xi_2^2}{4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 - \eta_1^2 + \eta_2^2}$$

$$\text{False } z_1 = -\text{ false } z^2 = \eta_1\left(1 - \frac{1}{2\eta_1^2}\,\frac{4\xi_1\xi_2\eta_1^2 - \xi_1^2(\eta_2^2-\eta_1^2) - \xi_1^2\xi_2^2}{4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 - \eta_1^2 + \eta_2^2}\right)\sqrt{-1}.$$

We thus see that, by neglecting the resistance, we get for the value of $z_1$ a quantity which requires only a minute correction in order to give the imaginary part of the true $z_1$. The same thing is not true for $z_3$ and $z_4$. Now, $\eta_1$ is $\odot$ divided by the principal period of oscillation of the pendulum upon the flexible stand. This is the quantity which we wish to determine; the others have only to be known approximately for the purpose of calculating the small correction to this. The logarithmic decrement of the amplitude of oscillation of the pendulum in the unit of time, so far as it is due to internal friction, is the quantity $\xi_1$. After these two quantities have been approximately ascertained, we may approximate to the quantity $(\xi_2^2+\eta_2^2)$ by means of the equation

$$(\xi_1^2+\eta_1^2)\,(\xi_2^2+\eta_2^2) = \frac{\gamma g}{l-h}.$$

Then, by eliminating $a$ between the two equations

$$2(\xi_1+\xi_2) = \frac{al}{l-h},$$

$$2[(\xi_1^2+\eta_1^2)\xi_2 + (\xi_2^2+\eta_2^2)\xi_1] = \frac{ag}{l-h},$$

we obtain $\xi_2$, and consequently $\eta_2$. The values so obtained must satisfy the equation

$$4\xi_1\xi_2 + \xi_1^2 + \xi_2^2 + \eta_1^2 + \eta_2^2 = \frac{\gamma l + g}{l-h}.$$

Before proceeding to the consideration of the elastic after-effect, I propose to apply the equations thus obtained to the calculation of the correction of the seconds' pendulum for the flexure of the stand, supposing the internal friction to be proportional to the velocity.

For the pendulum used by me we have the approximate values—

$l=1.00$; $h$ (heavy end up)$=0.30$; $h$ (heavy end down)$=0.70$; $g$ (New York)$=0.993\times\odot^2=9.89$; $\gamma=\frac{1}{0.0002125}=4706$; $\eta_1=1.00$.

The accompanying table shows that $\xi_1=0.000008$. From this we calculate that with heavy end up $\xi_2=0.08$, $\eta_2=257$; with heavy end down $\xi_2=0.17$, $\eta_2=392$. From this it appears that the correction of $\eta_1$ is absolutely insensible, or, in other words, the effect of resistance (supposed proportional to the velocity) vanishes. That this is nearly, in fact, the case for my instrument is shown by the circumstance that the times of oscillation upon stands of different rigidities agree with the values calculated in leaving the internal friction out of account.

*U. S. Coast Survey. Pendulum. Decrement of Arc due to internal friction of brass of tripod. Pendulum was swung on brass tripod in Paris, Geneva, and Kew. On a stand ten times as stiff in Hoboken. The times of decrement given are the* SUM *of the times with the heavy end up and heavy end down.*

| Half amplitude. | Time decrement on— |  | Time shortened by internal friction. | Ratio of shortening. | Decrement in one second. | Decrement due to internal friction in one second. | Mean arc. | Natural logarithmic decrement due to internal friction. |
|---|---|---|---|---|---|---|---|---|
|  | Flexible stand. | Stiff stand. |  |  |  |  |  |  |
| 100′ |  |  |  |  |  |  |  |  |
|  | 1073ˢ | 1095ˢ | +22s | .022 | 0′.0186 | .00023 | 90′ | .0000025 |
| 80 |  |  |  |  |  |  |  |  |
|  | 706 | 762 | +56 | .080 | .0142 | .00114 | 75 | .0000152 |
| 70 |  |  |  |  |  |  |  |  |
|  | 1927 | 1969 | +42 | .020 | .0104 | .00037 | 60 | .0000062 |
| 50 |  |  |  |  |  |  |  |  |
|  | 1377 | 1254 | Reject. |  |  |  |  |  |
| 40 |  |  |  |  |  |  | Mean | .000008 |

The last interval is probably affected by an error in the graduation of the scale used on one of the stands.

M. Plantamour proposes to determine the effect of the internal friction of the pendulum stand upon the correction for flexure, by means of the difference between the statical and dynamical flexure. He has made numerous observations, which, according to his own interpretation of them, would show that, if a pendulum be supported in a certain inclined position until the stand has had time to take its position of equilibrium under this force, and then be let go, the ratio of the amplitude of oscillation of the stand to that of the pendulum is not the initial one, but is very different from that. If this were the case, the motion of the stand and pendulum could not be represented, even approximately, in the form (1), for by those equations the logarithmic decrement of the oscillation of the stand is the same as that of the pendulum. It is true that the two parts of the oscillation (nearly in the natural periods of the pendulum and of the stand) have different logarithmic decrements; and, as the ratio of their amplitudes is not the same for the stand and for the pendulum, a certain change in the total relative amplitude might occur in this way, but only an excessively minute one, nothing like what M. Plantamour thinks he has observed. But it is so improbable that the motions of the stand and pendulum depart much from the forms (1) that it would be wrong to accept M. Plantamour's results until they are confirmed by a purely optical observation free from any possible influence from the machinery attached to the stand. Such an observation has been made by me, and, though I admit it was rather rough, it is entirely opposed to M. Plantamour's conclusions. Should the latter be confirmed, they would totally nullify the attempt to correct for the effect of flexure, as they would show the inapplicability of the analysis which has been proposed for the solution of that problem without affording us much hope of being able to replace it; and it would seem to be necessary in that case to reject all the work which has been done with the reversible pendulum.

If the pendulum were started in the manner proposed, and if for any cause the amplitudes of pendulum and stand were altered in different ratios, there would be a perpetual force at work tending to restore the old ratio, so long as the phases of the motion were the same in the pendulum and stand. But, if the phases differed, a part of this force would go to diminishing the amplitudes, and would act so strongly in this way that there would be a rapid decrement on account of this circumstance. Suppose, for instance, that in the differential equations we were to put instead of $D_t^2s$, $D_t^2s_1$, where $s$ is the value of $s$ at a time later than $t$ by a constant. The result of this would be (neglecting terms involving $a$) that instead of the square of the exponent of the Naperian base being the sum of two negative quantities, one of them very small compared with the other, the smaller of these quantities would be multiplied by an imaginary root of unity. This would have but little effect on the imaginary part of the exponent of base, which determines the period; but it would add a considerable real part, which would represent a corresponding decrement of arc.

It seems difficult to conceive of a force which should greatly change the relative amplitudes of oscillation of the pendulum and stand, without at the same time producing an enormous decrement of the amplitude of oscillation, such as certainly does not exist. It is for those who believe that the existence of such a force has been experimentally proved to show how great an effect it would have upon the period of oscillation. M. Plantamour supposes that the formula given by me in my paper, "De l'influence de la flexibilité du trépied sur l'oscillation du pendule à reversion," would still apply to such a case; but I am unable to see upon what ground.

Meantime, in the present state of the question, it appears to me that we must appeal to direct experiment to determine the difference between the time of oscillation on a stiff and on a flexible stand. Such experiments were given by me in the paper above mentioned, and I have since greatly multiplied experiments on a stiff stand, with the general result there announced, namely, that the difference is slightly greater than my theory supposes (owing, perhaps, to neglecting the energy of movement of the support), and not smaller, as M. Plantamour's views would require.

## ON THE EFFECT OF THE VERTICAL ELASTICITY OF A PENDULUM SUPPORT.

Let $s$ = the amount of depression of the support below its mean position;
$e$ = the force of restitution;
$l$ = the length of the simple equivalent pendulum;
$h$ = the distance of the point of support from the center of mass of the pendulum;
$\varphi$ = the angle which the axis of the pendulum makes with the vertical;
$r$ = the perpendicular distance of a given particle of the pendulum from the knife-edge;
$\omega$ = the angle which $r$ makes with the plane through the knife-edge and the axis of the pendulum.

The horizontal velocity of a particle $m$ is

$$r \cos(\varphi+\omega)\, D_t\varphi.$$

The vertical velocity is

$$r \sin(\varphi+\omega)\, D_t\varphi - D_t s.$$

The vis viva of the particle is, then,

$$\frac{1}{2} mr^2(D_t\varphi)^2 - mr \sin(\varphi+\omega) D_t\varphi \,.\, D_t s + \frac{1}{2} m(D_t s)^2.$$

The vis viva of the pendulum is

$$\frac{1}{2} Mlh(D_t\varphi)^2 - Mh \sin\varphi D_t\varphi \,.\, D_t s + \frac{1}{2} M(D_t s)^2.$$

The potential energy of the pendulum is

$$Mg(h - h\cos\varphi) + \frac{1}{2} es^2.$$

Lagrange's equations are consequently

$$MlhD_t^2\varphi - Mh \sin\varphi D_t^2 s = -Mgh \sin\varphi,$$

$$-Mh \sin\varphi D_t^2\varphi - Mh \cos\varphi (D_t\varphi)^2 + MD_t s = -es.$$

If S be the amount by which the stand is statically compressed by the weight of the pendulum, then $e = Mg:S$, so that the equations become

$$lD^2_t\varphi - \sin\varphi D^2_t s = -g \sin\varphi, \qquad (1)$$

$$-h \sin\varphi D_t\varphi - h\cos\varphi (D_t\varphi)^2 + D^2_t s = -\frac{g}{S} s. \qquad (2)$$

It is evident that small changes in $\varphi$ will affect $s$ insensibly, so that in determining $s$ we may assume

$$\sin\varphi = \varphi, \qquad \cos\varphi = 1, \qquad \varphi = \Phi \cos\sqrt{\frac{g}{l}}t.$$

The second equation then becomes

$$D^2_t s + \frac{g}{S} s = -\frac{gh\Phi^2}{l} \cos 2\sqrt{\frac{g}{l}}.t,$$

whence

$$s = \frac{hS}{4S-l} \Phi^2 \cos 2\sqrt{\frac{g}{l}}t + C\cos\sqrt{\frac{g}{S}}(t-t_0).$$

The second term may obviously be neglected, and 4S may be neglected in comparison with $l$, so that

$$s = -\frac{hS}{l} \Phi^2 \cos 2\sqrt{\frac{g}{l}}t,$$

$$D^2_t s = \frac{4ghS}{l^2} \Phi^2 \cos 2\sqrt{\frac{g}{l}}t = \frac{4ghS}{l^2}(2\varphi^2 - \Phi^2).$$

Then the first equation becomes

$$D^2_t\varphi = -\frac{g}{l}\left(1 + 4\frac{Sh}{l^2}\Phi^2\right)\varphi + \frac{g}{6l}\left(1 + 48\frac{Sh}{l^2}\right)\varphi^3,$$

after substituting $\varphi-\frac{1}{6}\varphi^3$ for sin $\varphi$, &c. Or, more briefly,

$$D_t{}^2\varphi=-g'\varphi+\tfrac{1}{6}g''\varphi^3.$$

Putting $\varphi=\sqrt{\frac{g'}{g''}}\theta$, we get

$$D_t{}^2\theta=-g'\theta+\tfrac{1}{6}g'\theta^3,$$

whence

$$\begin{aligned}
T&=\circledcirc\sqrt{\frac{l}{g'}}\left(1+\tfrac{1}{16}\ \Phi^2\right)\\
&=\circledcirc\sqrt{l}\left(1+\tfrac{1}{16}\frac{g''}{g'}\Phi^2\right)\\
&=\circledcirc\sqrt{\frac{\ }{g}}\left(1-\frac{2Sh}{l^2}\Phi^2\right)\left(1+\tfrac{1}{16}\Phi^2+\frac{3Sh}{l^2}\Phi^2\right)\\
&=\circledcirc\sqrt{\frac{l}{g}}\left(1+\tfrac{1}{16}\Phi^2+\frac{Sh}{l^2}\Phi^2\right).
\end{aligned}$$

If $\frac{S}{l}=.0001$, $\frac{h}{l}=.7$, and $\Phi=.05$, then $\frac{Sh}{l^2}\Phi^2=.000000175$.
so that the effect of the vertical elasticity of the support is insensible in ordinary cases.

# APPENDIX No. 15.

## ON THE DEDUCTION OF THE ELLIPTICITY OF THE EARTH FROM PENDULUM EXPERIMENTS.

By C. S. PEIRCE, Assistant.

Any correction to pendulum experiments whose magnitude changes progressively with the latitude needs to be very accurately determined, lest an error be thereby introduced into the resulting value of the ellipticity of the earth. The atmospheric pressure and the temperature both give rise to corrections of this class, and the coefficients of these corrections have been, in general, very inadequately determined. The experiments which have recently been published in the fifth volume of the India Survey, however, sufficiently determine these coefficients for the Kater invariable pendulums. For all other forms of pendulums which have been used, excepting the large-sized Repsold reversible pendulum, their values are quite uncertain. But by far the greater part of the valuable data at hand in reference to the relative force of gravity in different latitudes consist of the times of oscillation of Kater invariable pendulums. So that even were we able properly to correct the others for temperature and pressure they would have very little influence upon the resulting ellipticity, for their absolute number is small, and they are not usefully distributed in latitude. Subject to uncertainties of reduction as they are, the only appreciable effect of admitting them into our calculations would be to increase the apparent probable error without altering the result. Under these circumstances, it has seemed best to me in making a new calculation of the ellipticity, as derived from this class of experiments, to restrict myself exclusively to those made with the Kater invariable pendulums.* The coefficient of the effect of atmospheric pressure upon pendulums of this class was determined in 1829, by Sabine, and the later researches under the auspices of the Indian Survey have not seriously invalidated his determinations. Baily, in his report on Foster's pendulum experiments, undertook to correct all the former results for this effect, but his work is erroneous in several particulars. Thus, he applies the correction to Lütke's numbers, to which it had already been rightly applied; he omits to reduce Sabine's values to the level of the sea, and commits various other errors which cannot be so easily explained in a few words. For the coefficient of temperature effect a value has usually been assumed which was first obtained by Kater, and which is entirely incompatible with the known coefficient of the expansion of brass and with the experiments upon the periods of oscillation at different temperatures. The value adopted in the reductions of the India Survey for pendulum No. 4, which was one of Sabine's pendulums, coincides precisely with that found by Lütke; differs very little from that obtained by the Indian Survey for their other pendulum, satisfies well the experiments by Sabine at different temperatures, agrees with our general knowledge of the coefficient of expansion of brass, and has consequently been made use of by me in the reduction of all the experiments made with the Kater invariable pendulums. I have, therefore, made the necessary corrections to all the results with these pendulums, with the exception of those of the Indian series and of Lütke, which I have supposed to have been rightly reduced.

The corrections for elevation of the station above the level of the sea has hitherto been made by Dr. Young's rule, which is based on the assumption that all the earth and rock rising above the level of the sea is to be considered as attracting the pendulum as if it was so much additional matter beneath the pendulum in excess of what is found at the level of the sea. That this assumption, so foreign to the facts of the case, does not accord with the determinations of gravity made at the sea shore, and at great elevations in the neighborhood, has often been pointed out; in particular by M. Faye in the "Comptes Rendus," June 21, 1880.

Let us first consider the question *à priori*.

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* The present computation was begun before Major Herschel's work was received. The principles of my procedure being different from his, I have thought it worth while to complete my work and see how far Major Herschel's and my results would agree.

The only geological cause of vast horizontal displacements of solid matter, such as alone could sensibly affect the pendulum, is denudation. This has always been at work to remove matter from the continents and deposit it on the bed of the ocean; and it seems probable that the general result of it must have been to diminish the amount of matter in those cones having their vertices at the center of the earth and their bases on our present land, and to increase the amount of matter in those cones having their bases on our present sea bed. But it would seem that the effect of such transfer is one of those of which we cannot at present take account. We must, then, regard continental elevations, as produced by the elevation of a certain thickness of matter, equivalent to a crust.

If we use the following notation:

$g$=gravity,
$\delta$=density of the continent,
$\Delta$=mean density of the earth,
$c$=radius of the earth,
$u$=length of the chord from the center to the circumference of a small circle,
$h$=elevation above the level of the sea,

then the vertical attraction of a cap of matter having the thickness $h$ all over this small circle upon the point at its center is, according to Pratt,

$$\frac{3}{2} g \frac{\delta}{\Delta} \frac{1}{c} \left( u+h-\sqrt{u^2+h^2}+\frac{uh}{2c} \right)$$

It has always been assumed that the second term of the polynomial in the parenthesis would alone be sensible except in extreme cases. If, now, we conceive that the elevation, instead of being produced by the addition of new matter, has been produced by the upheaval of the crust of thickness $t$, then the quantity in the parenthesis becomes

$$u+\sqrt{u^2+(t+h)^2}-\sqrt{u^2+t^2}-\sqrt{u^2+h^2}$$

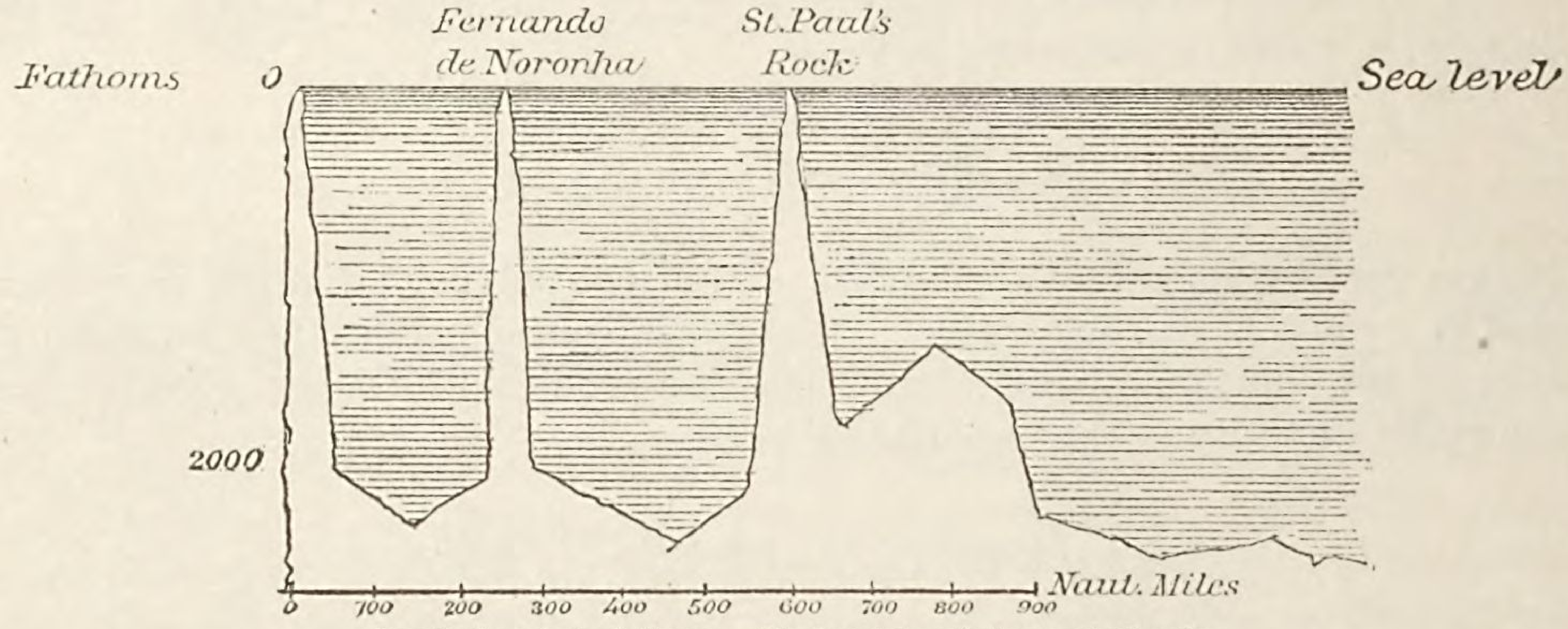
Here we perceive that that term which has generally been considered as alone sensible here disappears altogether; but a new term enters in of the first degree in $h$, the value of which is

$$\frac{t\,h}{\sqrt{u^2+t^2}}.$$

It will be seen that this term, which is the principal part of the whole expression, is nearly inversely proportional to the radius of the cap, so that a large cap will have less downward attraction than a small one. The reason of this is as follows:

Through any point, $p$, let a line be drawn in a vertical direction; through $p$ let a sphere be described having its center upon this line. Taking $p$ as the origin of polar co-ordinates, let a new surface be described having the radius vector in any direction equal to that of the sphere. Then this surface will be the surface upon which a particle of matter anywhere placed will exert a constant vertical attraction upon the point $p$. As the center of the sphere varies its position along the vertical line through $p$, a succession of these inclosed surfaces of equal vertical attraction will be formed all in contact with one another at the point $p$. It will be seen then that the nearly spherical surface of the earth cuts all these surfaces in such a manner that the uplifting of the particles anywhere on its surface other than the immediate neighborhood of $p$ will diminish the vertical attraction upon $p$. The exact calculation of the effect of the elevation of a crust being extremely troublesome, and the quantity being small, I have thought it sufficient to assume that the downward attraction would be one-tenth of the correction for elevation. This quantity which was adopted as satisfying moderately well the experiments on neighboring high and low levels is equivalent to assuming that the thickness of the crust is about one-eighth of the diameter of the space arched over; and the assumption has the same effect as if it were supposed that the continental elevations were produced by additional matter having three-fourths the density of water.

We have so far only considered the solid material of the crust. In addition to this there is the water, which simply runs down to the lowest levels; so that its whole attraction is to be considered and allowed for. Let us consider a small island lying in the midst of the sea. In the first place, if there were no water about it, the gravity would be in excess upon such an island in consequence of the depression of the sea-bed around it. This excess may, as we have seen, be roughly taken as equal to what would be produced by the downward attraction of an excess of matter sufficient to build up the island and having three-fourths the density of water. In the case of a small island the effect will be greater than this. In the case of a large island, especially one lying near a continent, the effect will be increased by the surrounding deposits of matter resulting from denudation. On the whole, then, we may roughly take the excess of gravity on the island to what it would be if the island was built up of extra matter having the density of water. Then when we take into account the attraction of the ocean itself, we may say that the excess of gravity upon an island will be about equal to what would be produced by an ocean having the general depth of the ocean bed quite outside the island and extending completely over the space occupied by the island. What is meant will be understood the moment that we look at a rough profile of the equatorial Atlantic through the islands Fernando de Noronha and Saint Paul's Island.



Vertical scale in fathoms. Horizontal scale in nautical miles.

Coast stations are generally to be considered as really continental, since the true boundary of the continent at a depth of some 100 fathoms is considerably outside the coast. Stations near this boundary may be considered to be like deep-water islands surrounded by water of half the depth of that which is upon one side of the station. Taking the contour chart of the ocean bed given in Mr. Wild's book called Thalassa, I find that the following pendulum stations have to be corrected for the depth of the ocean about them:

*Stations at which corrections are to be applied for attraction of water.*

| | Fathoms. |
|---|---|
| Hare Island | 1,000 |
| Melville Island | 1,000 |
| Galapagos | 2,000 |
| St. Thomas | 3,000 |
| Ascension | 2,000 |
| Sierra Leone | 500 |
| Bahia | 1,000 |
| Jamaica | 700 |
| Spitzbergen | 500 |
| Point Bowen | 500 |
| Valparaiso | 250 |
| Port La Coquille | 3,000 |
| Guaan | 3,000 |
| Port Lloyd | 2,000 |
| St. Helena | 2,000 |
| Montevideo | 200 |

| | Fathoms. |
|---|---|
| Staten Island | 500 |
| South Shetland | 500 |
| Cape Horn | 500 |
| Fernando de Noronha | 3,000 |
| Minicoy Island | 500 |

Rough as these corrections are, the application of them will show what we have to expect from a more exact treatment according to the principles just laid down. I have calculated the ellipticity with these corrections, and find it to be (taking $\eta=.0052375$)

$$\frac{1}{291.5\pm0.9}$$

This probable error is rather smaller than that obtained by the treatment of the latest and best geodetical operations and is much smaller than that obtained hitherto from pendulum observations. Upon comparing my residuals with those of Clarke (Geodesy, p. 349), it will be observed that, as a general rule, the residuals that now remain large had previously been much larger, and are generally marine stations, from whence I infer that a more careful estimate of the attraction of the ocean would produce a still further improvement of the result. That which is most needed to improve the state of our knowledge of gravity are additional experiments in the Arctic Circle. It is desirable that these experiments should be made with the Indian apparatus, and it is also to be desired that the same apparatus should be used at Trinidad, Ascension, and Maranham, the three stations which are common to the great expeditions of Sabine and Foster.

## *PENDULUM EXPEDITIONS.*

### ABBREVIATIONS AND FORMULÆ.

$$\left.\begin{matrix}\mathrm{E}\\ \mathrm{A}\\ \mathrm{T}\end{matrix}\right\}=\text{Author's corrections for}\left\{\begin{matrix}\text{Elevation.}\\ \text{Atmospheric effect.}\\ \text{Expansion of bar from } 62^\circ\text{ F.}\end{matrix}\right.$$

$$\left.\begin{matrix}\delta\mathrm{E}\\ \delta\mathrm{A}\\ \delta\mathrm{T}\end{matrix}\right\}=\text{Corrections to the above}\left\{\begin{matrix}\mathrm{E}+\delta\mathrm{E}=\mathrm{E}'\\ \mathrm{A}+\delta\mathrm{A}=\mathrm{A}'\\ \mathrm{T}+\delta\mathrm{T}=\mathrm{T}'\end{matrix}\right.$$

$$\left.\begin{matrix}e\\ a\\ t\end{matrix}\right\}=\text{corrected by}\left\{\begin{matrix}\mathrm{E}\\ \mathrm{A}\\ \mathrm{T}\end{matrix}\right.$$

$$\left.\begin{matrix}\bar{e}\\ \bar{a}\\ \bar{t}\end{matrix}\right\}=\text{uncorrected.}$$

$$\left.\begin{matrix}e'\\ a'\\ t'\end{matrix}\right\}=\text{corrected for}\left\{\begin{matrix}\mathrm{E}+\delta\mathrm{E}\\ \mathrm{A}+\delta\mathrm{A}\\ \mathrm{T}+\delta\mathrm{T}\end{matrix}\right.$$

$$\left.\begin{matrix}\bar{e}'\\ \bar{a}'\\ \bar{t}'\end{matrix}\right\}=\text{uncorrected.}$$

Temperature factor=.458 oscillation per degree for 86,400 oscillations per day.

Atmospheric factor$=.345\,\frac{\beta}{1+.0023\,(t-32^\circ)}$ or preferably $=\frac{1.655}{8.61}\times$ times old correc.

where sp. gr.=8.61 $\beta$=ht. of bar. $t$=F. ther.

## EXPEDITION No. I.

[Kater's, 1818–'19.—Pendulum not numbered; coefficient for expansion of bar .423 oscillation per degree Fahrenheit; specific gravity of pendulum taken at 8.61; no atmospheric effect except buoyancy allowed for. Phil. Trans. 1819.]

| Stations. | Latitude. | Oscil. per day. $\bar{e}$ $\bar{a}$ $t$ | Mean temp. | A | δT | A′ | Oscil. per day. $\bar{e}'$ $a'$ $t'$ |
|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | |
| London (Mr. Browne's) | 51 31 08 | 86, 055. 36 | 70. 5 | +5. 91 | +0. 32 | + 9. 85 | 86, 065. 53 |
| Unst | 60 45 28 | 90. 77 | 57. 8 | 6. 07 | — . 16 | 10. 02 | 100. 63 |
| Portsoy | 57 40 59 | 79. 77 | 60. 5 | 6. 05 | — . 06 | 10. 00 | 089. 71 |
| Leith Fort | 55 58 41 | 73. 16 | 57. 0 | 6. 05 | — . 18 | 10. 00 | 082. 98 |
| Clifton | 53 27 45[*] | 62. 01 | 55. 0 | 5. 94 | — . 26 | 9. 80 | 071. 55 |
| Arbury Hill | 52 12 55 | 56. 88 | 52. 9 | 6. 04 | — . 34 | 9. 97 | 066. 51 |
| London (Mr. Browne's) | 51 31 8 | 55. 12 | 51. 8 | 6. 18 | — . 23 | 10. 20 | 065. 09 |
| Shanklin Farm | 50 37 24 | 51. 28 | 60. 9 | +6. 09 | — . 04 | +10. 05 | 061. 29 |

[*] See Phil. Trans., 1823, p. 325.

## EXPEDITION No. II.

[Sabine's first voyage. Pendulum No. 2 in Shelton clock No. 2. Temp. coefficient 0.439 oscillations per degree Fahr.; specific gravity pendulum, 8.4. Correction for buoyancy only. Phil. Trans., 1821.]

| Station. | Latitude. | Oscil. per day. $e$ $a$ $t$ 50° | Mean temp. | E | A | T | δA | T′ | Oscil. per day. $\bar{e}'$ $a'$ $t'$ 62° |
|---|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | | | |
| Brassa | 60 09 42 | 86, 530. 51 | 54. 6 | +. 10 | +6. 24 | +2. 02 | +4. 09 | −3. 39 | 86, 529. 09 |
| Hare Island | 70 26 19 | 562. 64 | 44. 7 | +. 18 | +6. 45 | −2. 29 | +4. 22 | −7. 92 | 561. 05 |
| London (Mr. Browne's) | 51 31 08 | 497. 38 | 44. 5 | +. 35 | +6. 46 | −2. 39 | +4. 23 | −8. 01 | 495. 64 |

## EXPEDITION No. III.

[Sabine's second voyage. Pendulums Nos. 1 and 2 in Shelton clocks Nos. 1 and 2. Survey each in its own clock and each in other's clock. Same reductions as above. Same memoir.]

| Station. | Latitude. | Oscil. per day. $e$ $a$ $t$ 45° | Mean temp. | E | A | T | δA | T′ | Oscil. per day. $\bar{e}'$ $a'$ $t'$ 62° |
|---|---|---|---|---|---|---|---|---|---|
| | | Each pendulum in its own clock. | | | | | | | |
| | ° ′ ″ | | ° | | | | | | |
| London (Mr. Browne's) | 51 31 08 | 86, 444. 78 | 47. 7 | +. 35 | +6. 39 | +1. 41 | +4. 19 | −6. 55 | 86, 440. 66 |
| Melville Island | 74 47 12 | 519. 17 | 46. 5 | +. 14 | +6. 39 | +0. 67 | +4. 19 | −6. 76 | 515. 79 |
| London on return | 51 31 08 | 444. 65 | 51. 4 | +. 35 | +6. 32 | +2. 81 | +4. 14 | −4. 85 | 440. 78 |
| | | Each pendulum in the other's clock. | | | | | | | |
| London | 51 31 08 | 86, 446. 58 | 48. 4 | +. 35 | +6. 41 | +1. 49 | +4. 20 | −6. 23 | 456. 30 |
| Mellville Island | 74 47 12 | 541. 46 | 45. 7 | +. 14 | +6. 36 | +0. 30 | +4. 17 | −7. 47 | 531. 36 |

## EXPEDITION No. IV.

[Hall's, 1820–'23.—Number of pendulum not given. Coefficient for expansion of bar, .423 oscillation per degree Fahr. Specific gravity of pendulum not given. Reduced by author to 68° Fahr. Phil. Trans., 1823.]

| Stations. | Latitude. | Oscil. per day. $\bar{e}$ $\bar{a}$ $t$ 68° | Bar. | Mean temp. | δT. | A′ | Oscil. per day. $\bar{e}'$ $a'$ $t'$ 68° | Oscil. per day. $\bar{e}'$ $a'$ $t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | *in.* | ° | | | | |
| London (Mr. Browne's), rejected by author | 51 31 8 | 86, 229. 78 | 30. 08 | 66. 5 | —. 05 | +9. 87 | 86, 239. 60 | 86, 242. 35 |
| Earl of Abingdon's Island | 0 32 19 | 095. 54 | 29. 93 | 80. 9 | +. 45 | 9. 51 | 105. 50 | 108. 25 |
| San Blas de California | 21 32 24 | 119. 60 | 29. 80 | 83. 0 | +. 52 | 9. 45 | 129. 57 | 132. 32 |
| Rio de Janeiro | 22 55 22 | 125. 62 | 29. 84 | 74. 6 | +. 23 | 9. 60 | 135. 45 | 138. 20 |
| London | 51 31 8 | 230. 80 | 29. 83 | 66. 9 | —. 04 | +9. 77 | 240. 53 | 243. 28 |

## EXPEDITION No. V.

[Goldingham's, 1820–'23. Pendulum not numbered. Sp. gr. taken at 8.02; Baily says it was 7.97. Coefficient for expansion of bar =. 423 oscillation per degree Fahr. Phil. Trans., 1822.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ \bar{a}\ t$ 70° | Temp. | Bar unred. | δT | A′ | Oscil. per day. $\bar{e}\ a'\ t'$ 70° | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | *in.* | | | | |
| London | 51 31 8 | 86, 293. 14 | 67. 6 | 29. 97 | −. 08 | +9. 77 | 86, 302. 83 | 86, 306. 49 |
| Madras | 13 4 9 | 166. 08 | 84. 5 | 30. 19 | +. 51 | +9. 67 | 86, 176. 27 | 86, 179. 93 |

## EXPEDITION No. VI.

[Brisbane's, 1821–'22. Pendulum not numbered. Coefficient for expansion of bar =.423 oscillation per degree Fahr. Specific gravity o pendulum taken at 8.00. Reduced by author to 60° Fahr. Phil. Trans., 1823.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ \bar{a}\ t$ 60° | Mean temp. | A | δT | δA | Oscil. per day. $\bar{e}'\ a'\ t'$ 60° | Oscil. per day. $\bar{e}'\ \bar{a}'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | | |
| London | 51 31 8 | 86, 083. 84 | 61. 8 | +6. 42 | +. 06 | +3. 90 | 86, 094. 22 | 86, 093. 30 |
| Paramatta | 33 48 43 | 15. 42 | 56. 8 | +6. 47 | —. 11 | +3. 93 | 25. 71 | 24. 79 |

## EXPEDITION No. VII.

[Sabine's (in the Pheasant), 1821–'24. Pendulums Nos. 3 and 4. Coefficient for expansion of bar =.42 (p. 16) oscillation per degree Fahr. Specific gravity of the pendulum taken at 8. 61. From "Sabine's Experiments to determine the figure of the Earth." London, 1825, p. 236 The corrections in the last column but one are given by Sabine. Phil. Trans., 1828, p. 77.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ a\ t$ 60° | Mean. temp. | T | A + | δT ± | δA + | Corr. | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | | | |
| St. Thomas | 0 24 41 | 86, 029. 40 | 81. 5 | +8. 24 | 5. 79 | +. 75 | 3. 79 | ....... | 86, 033. 90 |
| Maranham | − 2 31 43 | 019. 78 | 80. 9 | +7. 96 | 5. 78 | +. 72 | 3. 79 | —. 01 | 024. 28 |
| Ascension | − 7 55 48 | 033. 11 | 81. 1 | +8. 06 | 5. 80 | +. 73 | 3. 80 | ........ | 037. 64 |
| Sierra Leone | + 8 29 28 | 028. 14 | 80. 5 | +7. 80 | 5. 75 | +. 71 | 3. 77 | ........ | 032. 62 |
| Trinidad | +10 38 56 | 027. 31 | 82. 8 | +8. 78 | 5. 75 | +. 79 | 3. 77 | +. 04 | 031. 91 |
| Bahia | —12 59 21 | 032. 81 | 73. 2 | +4. 71 | 5. 88 | +. 43 | 3. 85 | +. 09 | 037. 18 |
| Jamaica | 17 56 7 | 045. 27 | 81. 6 | +8. 27 | 5. 78 | +. 75 | 3. 79 | —. 08 | 049. 73 |
| New York | 40 42 43 | 117. 97 | 34. 6 | —11. 51 | 6. 43 | —1. 04 | 4. 22 | —. 05 | 121. 10 |
| *London | 51 31 8 | 159. 79 | 62. 0 | ........ | ........ | ........ | ........ | ........ | 163. 29 |
| Drontheim | 63 25 54 | 198. 52 | 46. 7 | −6. 43 | 6. 16 | —. 58 | 4. 03 | ........ | 201. 97 |
| Hammerfest | 70 40 5 | 320. 96 | 49. 2 | −5. 36 | 6. 15 | —. 49 | 4. 03 | ........ | 224. 50 |
| Greenland | 74 32 19 | 230. 44 | 42. 3 | −8. 28 | 6. 26 | —. 75 | 4. 10 | ........ | 233. 79 |
| Spitzbergen | 79 49 58 | 242. 93 | 41. 0 | −8. 78 | 6. 27 | —. 79 | 4. 11 | ........ | 246. 25 |

* Specially computed from data given by Sabine.

## EXPEDITION No. VIII.

[Foster's first, 1824–'25. Pendulum No. 3. Coefficient for expansion of bar =. 423 oscillation per degree Fahr. Specific gravity of pendulum, 8. 61. Phil. Trans., 1826, IV.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ \bar{a}\ t$ 50° | Temp. | A | δT | δA | Oscil. per day. $\bar{e}\ \bar{a}'\ t'$ 50° | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | | |
| Greenwich | 51 28 40 | 86, 152. 87 | 56. 05 | +6. 06 | +. 21 | +3. 97 | 86, 163. 11 | 86, 157. 61 |
| Port Bowen | 73 13 39 | 86, 223. 87 | 50. 70 | +6. 14 | +. 02 | +4. 02 | 86, 234 05 | 86, 228. 55 |
| Greenwich | 51 28 40 | 86, 153. 13 | 44. 50 | +6. 04 | —. 19 | +3. 96 | 86, 162. 94 | 86, 157. 44 |

## EXPEDITION NO. IX.

[Luetke, 1829–'31.—Hall's pendulums. Reductions correct. St. Petersburg Acad. Sci. Divers Savans, Vol. III, 1837.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ a\ t$ 62° | | Oscil. per day. $\bar{e}\ a\ t$ 62° |
|---|---|---|---|---|
| | ° ′ ″ | | | |
| Petersburg | 59 56 30 | 86, 268. 86 | +. 28 | 86, 269. 14 |
| Greenwich | 51 28 40 | 86, 236. 09 | ....... | 86, 236. 09 |
| Valparaiso | −33 2 30 | 86, 165. 33 | +. 21 | 86, 165. 54 |
| New Archangel | 57 02 59 | 86, 257. 33 | +. 14 | 86, 257. 47 |
| Petropolowski | 53 0 59 | 86, 245. 50 | +. 07 | 86, 245. 57 |
| Port La Coquille | 5 21 16 | 86. 112. 64 | ±. 00 | 86, 112. 64 |
| Guahan | 13 26 18 | 86, 117. 84 | —. 07 | 86, 117. 77 |
| Port Lloyd | 27 4 9 | 86, 159. 00 | —. 14 | 86, 158. 86 |
| St. Helena | —15 55 3 | 86, 125. 19 | —. 21 | 86, 124. 98 |
| *By Captain Reinecke.* (Edges reground). | | | | |
| Kandalachka | 67 7 43 | 86, 300. 34 | ....... | 86, 300. 34 |
| Petersburg | 59 56 30 | 86, 279. 17 | ..... | 86, 279. 17 |

## EXPEDITION NO. X.

[Sabine's, 1827. Pendulums Nos. 7 and 8. Coefficient for expansion of bar =.421 oscillation per degree Fahr. Specific gravity of pendulums, 8. 61. Reduced to 58° at Paris and 60° at London. Phil. Trans., 1828.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ a\ t$ 60° | Mean temp. | A + | δT | A′ + | Oscil. per day. $\bar{e}\ a'\ t'$ 60° | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | | | | |
| Paris | 48 50 14 | 85, 927. 52 | 56. 88 | 6 04 | —. 12 | 10. 00 | 85, 937. 40 | 85, 936. 48 |
| London | 51 31 8 | 85, 939. 55 | 63. 36 | 6. 00 | +. 12 | 9. 93 | 85, 949. 60 | 85, 948. 62 |

## EXPEDITION NO. XI.

[Sabine's, 1829. Pendulum No. 12. Coefficient of expansion of bar =.43 oscillation per degree Fahr. for London-Greenwich, and 0.44 for Greenwich-Altona. Atmospheric reduction correctly made. Phil. Trans., 1829 and 1830.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ a\ t$ 62° | Mean temp. | δT | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|
| | ° ′ ″ | | ° | | |
| London (Mr. Browne's) | 51 31 8 | 85, 973. 57 | 62. 5 | +. 01 | 85, 973. 58 |
| Greenwich | 51 28 40 | 85, 974. 09 | 58. 92 | —. 09 | 74. 00 |
| Knife reground. | | | | | |
| London | 51 31 8 | 85,969. 34 | 71. 9 | +. 28 | 85, 969. 62 |
| Greenwich | 51 28 40 | 85, 969. 78 | 61. 5 | —. 01 | 69. 77 |
| | | To. 60° | | | |
| Greenwich | 51 28 40 | 85, 970. 77 | 63. 53 | +. 03 | 85, 969. 88 |
| Altona | 53 32 45 | 85, 979. 10 | 58. 32 | —. 06 | 978. 12 |

## EXPEDITION NO. XII.

[Fallow's, 1828–'29. Pendulum No. 4, as in Expedition No. VII. Coefficient for expansion of bar =.421 oscillation per degree Fahr. Specific gravity of pendulum, 8.60. Phil. Trans., 1830.]

| Station. | Latitude. | Oscil. per day. $\bar{e}\ a\ t$ 62° | Mean temp. | Bar. | A + | δT | δA | Oscil. per day. $\bar{e}\ a'\ t'$ 62° |
|---|---|---|---|---|---|---|---|---|
| | ° ′ ″ | | ° | *in.* | | | | |
| London (Mr. Browne's) | 51 31 8 | 86, 164. 62 | 70. 82 | 29. 80 | 5. 87 | +. 33 | 3. 84 | 86, 168. 79 |
| Cape of Good Hope | 33 55 56 | 85, 097. 72 | 71. 44 | 30. 03 | 5. 91 | +. 25 | 3. 87 | 86, 101. 94 |

## EXPEDITION No. XIII.

[Foster's, 1828–'31. Pendulums Nos. 10 and 11. Coefficient for expansion of bar = .422 oscillation per degree Fahr. Atmospheric effect correctly taken into account. Memoirs Royal Astron. Society, Vol. VII, 1834.]

MEANS FOR PENDULUMS 10 AND 11.

| Station | Latitude. | Oscil. per day. ē a t 62° | T | δT | Oscil. per day. ē a′ t′ 62° |
|---|---|---|---|---|---|
| | ° ″ ′ | | | | |
| London (Mr. Browne's; on Kater's support) | 51 31 8 | 86, 066. 48 | — 3. 24 | —. 28 | 86, 066. 20 |
| Greenwich | 51 28 40 | 86, 065. 59 | — 6. 31 | —. 54 | 86, 065. 05 |
| Montevideo | −34 54 26 | 86, 001. 70 | — 3. 69 | —. 31 | 86, 001. 39 |
| Staten Island | −54 46 23 | 86, 082. 04 | — 5. 87 | —. 50 | 86, 081. 59 |
| *South Shetland | —62 56 11 | 86, 111. 53 | −10. 76 | —. 92 | 86, 110. 65 |
| Cape Horn | —55 51 20 | 86, 084. 92 | — 8. 95 | —. 76 | 86, 084. 17 |
| Cape of Good Hope | —33 54 37 | 85, 998. 21 | — 1. 64 | —. 14 | 85, 998. 07 |
| St. Helena | —15 56 7 | 85, 954. 76 | + 6. 12 | +. 52 | 84, 955. 29 |
| Ascension | — 7 55 23 | 85, 939. 03 | + 8. 49 | +. 72 | 85, 939. 74 |
| †Green Mountains | — 7 58 00 | 85, 930. 68 | + 5. 31 | +. 45 | 85, 931. 13 |
| Fernando de Noronha | — 3 49 59 | 85, 938. 70 | + 7. 98 | +. 68 | 85, 939. 38 |
| Maranham | — 2 31 35 | 85, 925. 17 | + 8. 66 | +. 74 | 85, 925. 38 |
| Para | — 1 27 00 | 85, 927. 31 | + 8. 84 | +. 75 | 85, 928. 05 |
| Trinidad | +10 38 55 | 85, 934. 54 | + 9. 08 | +. 77 | 85, 935. 29 |
| Porto Bello | + 9 32 30 | 85, 939. 59 | + 6. 76 | +. 58 | 85, 940. 17 |
| ‡London (Mr. Baily's) | +51 31 8 | 86, 066. 50 | — 4. 03 | —. 34 | 86, 066. 10 |

[One-half mean difference of pendulum = 51. 71 St. Helena to Para.]

* No. 10 reduced to mean. † Pendulum No. 10 only used here. ‡ Pendulum No. 10 rejected, and also those of 1832 with pendulum No. 11.

## EXPEDITION No. XIV.

Murphy's, 1835. Pendulum No. 10. Coefficient for expansion of bar = .423 oscillations per degree Fahr. Atmospheric effect correctly taken into account. Memoirs Ast. Soc., XII.]

| Station. | Latitude. | Oscil. per day. ē a t | T | δT | Oscil. per day. ē a′ t′ 62° |
|---|---|---|---|---|---|
| | ° ′ ″ | | | | |
| London (Baily's house) | 51 31 8 | 86, 021. 13 | — 7. 80 | —. 65 | 86, 020. 48 |
| Bir | 37 | 85, 960. 55 | — 7. 36 | —. 61 | 85, 959. 94 |
| Bussora | 30 30 | 85, 940. 73 | +11 13 | +. 93 | 85, 941. 66 |

## EXPEDITION No. XV.

[Maclear's, 1839. Pendulum No. 11. Coefficient for expansion of bar = .423 oscillations per degree Fahr. Atmospheric effect correctly taken into account. Memoirs Ast. Soc., XII.]

| Station. | Latitude. | Oscil. per day. ē a t 62° | T | δT | Oscil. per day. ē a t 62° |
|---|---|---|---|---|---|
| | ° ′ ″ | | | | |
| London (Baily's house) | 51 31 8 | 86, 116. 07 | +1. 31 | +. 11 | 86, 116. 18 |
| Cape of Good Hope | 33 56 3 | 86, 049. 40 | —1. 57 | —. 13 | 86, 049. 27 |

## EXPEDITION No. XVI.

Basevi and Heaviside, 1865 to 1874. Pendulums Nos. 4 and 1821. Coefficients of expansion =0.458 for pendulum No. 4 and 0.442 for pendulum No. 1821. G. T. Survey of India, Vol. 5 [p. 120], 1879.

| Station. | Latitude. | Oscil. per day. ē a t 62° |
|---|---|---|
| | ° ′ ″ | |
| Pannæ | 8 09 28 | 85, 982. 75 |
| Kúdankolam | 9 10 21 | 82. 56 |
| Minicoy | 8 17 01 | 87. 01 |
| Mallapatti | 9 28 45 | 82. 60 |
| Alleppy | 9 29 39 | 85. 89 |
| Pachapaliam | 10 59 40 | 82. 28 |
| Aden | 12 46 53 | 91. 67 |
| Mangalore | 12 51 37 | 88. 87 |
| Bangalore, South | 13 00 41 | 78. 49 |
| Bangalore, North | 13 04 56 | 79. 38 |
| Madras | 13 04 08 | 89. 03 |
| Namthábád | 15 05 52 | 87. 71 |
| Cocanáda | 16 56 21 | 98. 23 |
| Kodangal | 17 07 57 | 91. 01 |
| Damargida | 18 03 17 | 91. 04 |
| Colaba (Bombay) | 18 53 46 | 86, 005. 19 |
| Somtana | 19 05 00 | 85, 996. 27 |
| Badgaon | 20 44 23 | 86, 002. 26 |
| Calcutta | 22 32 55 | 12. 69 |
| Ahmadpúr | 23 36 21 | 08. 21 |
| Kaliánpúr | 24 07 11 | 10. 36 |
| Pahárgarh | 24 56 07 | 11. 10 |
| Usira | 26 57 06 | 21. 31 |
| Datairi | 28 44 05 | 26. 73 |
| Kalïana | 29 30 55 | 27. 25 |
| Nojli | 29 53 28 | 27. 62 |
| Dehra | 30 19 29 | 20. 86 |
| Mussoorie | 30 27 41 | 11. 59 |
| Ismailia | 30 35 55 | 35. 93 |
| Meean Meer | 31 31 37 | 34. 55 |
| Moré | 33 15 39 | 85, 984. 62 |
| Kew | 51 28 06 | 86, 119. 15 |

The results of Expeditions Nos. IX, XI, XII, XIII, XV have been reduced to VII by solving by least squares the following equations of condition:

| | *Obs.* | *Calc.* |
|---|---|---|
| VII at Greenwich — reduction of IX | = 4.9356890 | 6880 |
| VII at St. Helena — reduction of IX | = 4.9351291 | 1302 |
| VII at London — reduction of XI | = 4.9353550 | 3560 |
| VII at Greenwich — reduction of XI | = 4.9353564 | 3554 |
| VII at London — reduction of XII | = 4.9353500 | 3510 |
| VII at C. G. H. — reduction of XII | = 4.9350129 | 0119 |
| VII at London — reduction of XIII | = 4.9348326 | 8296 |
| VII at Greenwich — reduction of XIII | = 4.9348269 | 8289 |
| VII at C. G. H. — reduction of XIII | = 4.9344887 | 4904 |
| VII at St. Helena — reduction of XIII | = 4.9342726 | 2714 |
| VII at Maranham — reduction of XIII | = 4.9341242 | 1261 |
| VII at Ascension — reduction of XIII | = 4.9341940 | 1948 |
| VII at Trinidad — reduction of XIII | = 4.9341715 | 1691 |
| VII at London — reduction of XV | = 4.9350847 | 0855 |
| VII at C. G. H. — reduction of XV | = 4.9347472 | 7464 |
| VII at London | = 4.9353222 | 3224 |
| VII at Maranham | = 4.9346210 | 6190 |
| VII at Ascension | = 4.9346885 | 6877 |
| VII at Trinidad | = 4.0346596 | 6619 |

The following are the values of the unknown quantities:

Reduction of Expedition No. IX = − 3661
No. XI = + 9664
No. XII = − 284
No. XIII = + 4926
No. XIV = + 2371

Oscillations of VII at London = 4.9353224
Greenwich = 3218
C. G. H. = 4.9349833
St. Helena = 7642
Maranham = 6190
Ascension = 6877
Trinidad = 6619

### EXPEDITION NO. I.

Reduction to No. VII by London = + 4,943.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced. |
|---|---|---|---|---|---|---|
| London | 4. 9348281 | 3, 224 | 6, 448 | 39 | 13, 916 | 2, 571 |
| Unst | 50063 | 5, 006 | 10, 012 | 12 | 17, 283 | 2, 741 |
| Portsoy | 49512 | 4, 455 | 8, 910 | 39 | 16, 215 | 2, 734 |
| Leith Fort | 49173 | 4, 116 | 8, 232 | 28 | 15, 597 | 2, 663 |
| Clifton | 48597 | 3, 540 | 7, 080 | 141 | 14, 659 | 2, 562 |
| Arbury Hill | 48342 | 3, 285 | 6, 570 | 306 | 14, 184 | 2, 692 |
| Shanklin Farm | 48078 | 3, 021 | 6, 042 | 100 | 13, 570 | 2, 572 |

### EXPEDITION NO. II.

Reduction to No. VII from experiments in London = − 16,718.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced. |
|---|---|---|---|---|---|---|
| London | 4. 9369942 | 3, 224 | 6, 448 | 39 | 13, 916 | 2, 571 |
| Brassa | 4. 9371622 | 4, 904 | 9, 808 | 10 | 17, 081 | 2, 737 |
| Hare Island | 4. 9373225 | 6, 507 | 13, 014 | 18 | 20, 146 | 2, 876 |

### EXPEDITION NO. III.

Reduction to No. VII from experiments in London: For each pendulum in its own clock = − 13,957; for each pendulum in the other clock = − 14,742.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced. |
|---|---|---|---|---|---|---|
| London | 4. 9367181 | 3, 224 | | | | |
| London | 4. 9367966 | | | | | |
| Melville Island | 4. 9370954 | 6, 997 | 13, 994 | 14 | 21, 129 | 2, 879 |
| Melville Island | 4. 9371735 | 6, 993 | 13, 986 | 14 | 21, 129 | 2, 871 |

## EXPEDITION NO. IV.

Reduction to No. VII from experiments in London: Before St. Blas — 3,982; after Abingdon's Island — 4,029.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to No. VII. |
|---|---|---|---|---|---|---|
| London | 4. 9357206 | 3, 224 | ........ | ........ | ........ | ........ |
| Earl of Abingdon's Island | 4. 9350448 | 6, 466 | 2, 932 | 5 | 2 | 2, 935 |
| San Blas | 1662 | 7, 633 | 5, 266 | 48 | 3, 065 | 2, 249 |
| Rio de Janeiro | 1958 | 7, 929 | 5, 858 | 29 | 3, 449 | 2, 438 |
| London | 7253 | 3, 224 | ........ | ........ | ........ | ........ |

## EXPEDITION NO. V.

Reduction to No. VII from experiments at London = — 7,210.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to No. VII. |
|---|---|---|---|---|---|---|
| London | 4. 9360434 | 3, 224 | ........ | ........ | ........ | ........ |
| Madras | 4. 9354061 | 6, 851 | 3, 702 | 11 | 1, 163 | 2, 550 |

## EXPEDITION NO. VI.

Reduced to No. VII from experiments in London = + 3,531.

| Station. | Log No. oscillations. | Red. to VII −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| London | 4. 9349693 | 3, 224 | ........ | ........ | ........ | ........ |
| Paramatta | 4. 9346236 | 9, 767 | 9, 535 | 31 | 7, 038 | 2, 528 |

## EXPEDITION NO. VII.

| Station. | Log No. oscillations. | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced. |
|---|---|---|---|---|---|
| St. Thomas | 4. 9346696 | 3, 392 | 9 | 1 | 3, 400 |
| Maranham | 46210 | 2, 421 | 32 | 44 | 2, 409 |
| Ascension | 46885 | 3, 770 | 7 | 432 | 3, 345 |
| Sierra Leone | 46631 | 3, 263 | 79 | 496 | 2, 846 |
| Trinidad | 46595 | 3, 191 | 9 | 776 | 2, 424 |
| Bahia | 46861 | 3, 723 | 89 | 1, 149 | 2, 663 |
| Jamaica | 47495 | 4, 990 | 3 | 2, 156 | 2, 837 |
| New York | 51095 | 2, 191 | 28 | 9, 666 | 2, 553 |
| London | 53222 | 6, 445 | 39 | 13, 916 | 2, 568 |
| Drontheim | 55172 | 0, 344 | 51 | 18, 158 | 2, 237 |
| Hammerfest | 56307 | 2, 614 | 12 | 20, 206 | 2, 420 |
| Greenland | 56775 | 3, 550 | 13 | 21, 078 | 2, 485 |
| Spitzbergen | 57402 | 4, 805 | 9 | 21, 982 | 2, 832 |

## EXPEDITION NO. VIII.

Reduction = + 286.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| Greenwich | 4. 9352932 | 3, 218 | 6, 436 | 66 | 13, 900 | 2, 602 |
| Port Bowen | 6511 | 6, 797 | 3, 594 | 49 | 20, 802 | 2, 841 |

## EXPEDITION NO. IX.

Reductions = − 3,661 and = − 4,165.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| Petersburg | 4. 9358555 | 4, 894 | 4, 788 | 26 | 17, 006 | 2, 808 |
| Greenwich | 6890 | 3, 229 | 6, 459 | 66 | 13, 900 | 2, 625 |
| Valparaiso | 3336 | 9, 675 | 9, 350 | 5 | 6, 757 | 2, 558 |
| New Archangel | 7967 | 4, 306 | 8, 612 | 6 | 15, 985 | 2, 633 |
| Petropaulowski | 7368 | 3, 707 | 7, 414 | 32 | 14, 490 | 2, 956 |
| Port La Coquille | 0669 | 7, 008 | 4, 016 | 2 | 199 | 3, 819 |
| Guahan | 0927 | 7, 266 | 4, 533 | 2 | 1, 228 | 3, 709 |
| Port Lloyd | 2999 | 9, 338 | 8, 676 | 6 | 4, 730 | 3, 952 |
| St. Helena | 1291 | 7, 630 | 5, 260 | 15 | 1, 714 | 3, 561 |
| | | | | | | |
| Kandalachka | 4. 9360125 | 5, 960 | 1, 920 | 12 | 19, 266 | 2, 666 |
| Petersburg | 4. 9359059 | 4, 894 | ............ | ............ | ............ | ............ |

## EXPEDITION NO. X.

Reductions = + 10,834. Derived from London values.

| Station. | Log No. oscillations. | Red. to Sabine 21−24 −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| Paris | 4. 9341775 | 2, 609 | 5, 218 | 100 | 12, 873 | 2, 445 |
| London | 4. 9342389 | 3, 223 | 6, 447 | 39 | 13, 916 | 2, 570 |

## EXPEDITION NO. XI.

Reductions = $\left\{ {+9,561 \atop +9,767} \right\}$ Derived from London values.

| Station. | Log No. oscillations. | Red. to Sabine 21−24 −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| London | 4. 9343650 | 3, 211 | 6, 422 | 39 | 13, 916 | 2, 545 |
| Greenwich | 3671 | 3, 232 | 6, 464 | 66 | 13, 900 | 2, 630 |
| | | | | | | |
| London | 3450 | 3, 217 | 6, 434 | 39 | 13, 916 | 2, 557 |
| Greenwich | 3457 | 3, 224 | 6, 448 | 66 | 13, 900 | 2, 619 |
| | | | | | | |
| Greenwich | 4. 9343463 | 3, 230 | 6, 460 | 66 | 13, 900 | 2, 626 |
| Altona | 3879 | 3, 646 | 7, 292 | 41 | 14, 691 | 2, 642 |

## EXPEDITION NO. XII.

Reductions = − 284.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Reduced to VII. |
|---|---|---|---|---|---|---|
| Portland Place | 4. 9353500 | 3, 216 | 6, 432 | 39 | 13, 916 | 2, 525 |
| Cape of Good Hope | 4. 9350129 | 9, 845 | 9, 690 | 14 | 7, 073 | 2, 631 |

## EXPEDITION No. XIII.

Reduction = + 4,926.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. — | Reduced to VII. |
|---|---|---|---|---|---|---|
| London | 4. 9348326 | 3, 252 | 6, 504 | 39 | 13, 916 | 2, 627 |
| Greenwich | 48268 | 3, 194 | 6, 388 | 66 | 13, 900 | 2, 554 |
| Montevideo | 45055 | 9, 981 | 9, 962 | 5 | 7, 456 | 2, 511 |
| Staten Island | 49103 | 4, 029 | 8, 058 | 7 | 15, 151 | 2, 914 |
| S. Shetland | 50567 | 5, 493 | 0, 986 | 10 | 18, 000 | 2, 996 |
| Cape Horn | 49232 | 4, 158 | 8, 316 | 17 | 15, 550 | 2, 783 |
| Cape of Good Hope | 44888 | 9, 814 | 9, 628 | 14 | 7, 073 | 2, 569 |
| St. Helena | 42726 | 7, 652 | 5, 304 | 13 | 1, 714 | 3, 603 |
| Ascension | 41940 | 6, 866 | 3, 732 | 7 | 432 | 3, 307 |
| Green Mount | 41506 | 6, 432 | 2, 864 | 926 | 437 | 3, 353 |
| Fernando de Noronha | 41922 | 6, 848 | 3, 696 | 14 | 102 | 3, 608 |
| Maranham | 41242 | 6, 166 | 2, 332 | 32 | 44 | 2, 320 |
| Para | 41350 | 6, 276 | 2, 552 | 17 | 15 | 2, 554 |
| Trinidad | 41715 | 6, 641 | 3, 282 | 9 | 776 | 2, 515 |
| Porto Bello | 41962 | 6, 888 | 3, 776 | 5 | 625 | 3, 156 |
| London | 48321 | 3, 247 | 6, 494 | 43 | 13, 916 | 2, 621 |

## EXPEDITION No. XIV.

Reduction = + 7,205.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. — | Reduced to VII. |
|---|---|---|---|---|---|---|
| London (Mr. Baily's house) | 4. 9346018 | 3, 223 | 6, 447 | 39 | 13, 916 | 2, 570 |
| Bîr | 4. 9342961 | 0, 166 | 0, 332 | 270 | 8, 230 | 2, 372 |
| Bassorah | 4. 9342037 | 9, 242 | 8, 485 | 1 | 5, 856 | 2, 630 |

## EXPEDITION No. XV.

Reduction = + 2,371.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2 | Elevation corr. + | Latitude corr. — | Reduced to VII. |
|---|---|---|---|---|---|---|
| London (Mr. Baily's house) | 4. 9350847 | 3, 218 | 6, 446 | 39 | 13, 916 | 2, 564 |
| Cape of Good Hope | 4. 9347471 | 9, 842 | 9, 695 | 14 | 7, 073 | 2, 631 |

## EXPEDITION No. XVI.

Reduction = + 2,421. Reduction derived from Madras.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. — | Reduced to VII. |
|---|---|---|---|---|---|---|
| Punnae | 4. 9344113 | 6 534 | 3, 068 | 20 | 458 | 2, 630 |
| Kúdankolam | 4. 9344103 | 6, 524 | 3, 049 | 70 | 460 | 2, 659 |
| Minicoy | 4. 9344328 | 6, 749 | 3, 499 | 3 | 472 | 3, 030 |
| Mallapatti | 4. 9344105 | 6, 526 | 3, 053 | 120 | 617 | 2, 556 |
| Allepy | 4. 9344271 | 6, 692 | 3, 385 | 3 | 619 | 2, 769 |
| Pachapaliam | 4. 9344089 | 6, 510 | 3, 020 | 4 | 827 | 2, 197 |
| Aden | 4. 9344563 | 6, 984 | 3, 969 | 2 | 1, 113 | 2, 858 |
| Mangalore | 4. 9344422 | 6, 843 | 3, 686 | 3 | 1, 126 | 2, 563 |
| Bangalore South | 4. 9343898 | 6, 319 | 2, 638 | 1, 295 | 1, 151 | 2, 782 |
| Bangalore North | 4. 9343943 | 6, 364 | 2, 728 | 1, 250 | 1, 165 | 2, 803 |
| Madras | 4. 9344430 | 6, 851 | 3, 703 | 11 | 1, 163 | 2, 551 |

## EXPEDITION NO. XVI—Continued.

Reduction = + 2,421. Reduction derived from Madras.

| Station. | Log No. oscillations. | [Red. to Sabine] −4.935 | Mult. by 2. | Elevation corr. + | Latitude corr. − | Sabine. |
|---|---|---|---|---|---|---|
| Namthábád | 4. 9344363 | 6, 884 | 3. 769 | 487 | 1, 542 | 2, 714 |
| Cocanáda | 4. 9344895 | 7, 316 | 4, 633 | 3 | 1, 931 | 2, 705 |
| Kodangal | 4. 9344530 | 6, 951 | 3, 903 | 796 | 1, 974 | 2, 725 |
| Damargída | 4. 9344532 | 6, 953 | 3, 906 | 809 | 2, 184 | 2, 531 |
| Colaba-Bombay | 4. 9345246 | 7, 667 | 5, 335 | 14 | 2, 385 | 2, 964 |
| Somtana | 4. 9344796 | 7, 217 | 4, 435 | 711 | 2, 430 | 2, 716 |
| Badgaon | 4. 9345099 | 7, 520 | 5, 040 | 465 | 2, 852 | 2, 653 |
| Calcutta | 4. 9345625 | 8, 046 | 6, 092 | 8 | 3, 422 | 2, 678 |
| Ahmadpúr | 4. 9345398 | 7, 819 | 5, 639 | 704 | 3, 638 | 2, 705 |
| Kaliánpúr | 4. 9345507 | 7, 928 | 5, 856 | 732 | 3, 792 | 2, 796 |
| Pahárgarh | 4. 9345545 | 7, 966 | 5, 932 | 682 | 4, 041 | 2, 573 |
| Usira | 4. 9346060 | 8, 481 | 6, 963 | 337 | 4, 670 | 2, 630 |
| Datairi | 4. 9346334 | 8, 755 | 7, 510 | 298 | 5, 254 | 2, 554 |
| Kaliána | 4. 9346360 | 8,781 | 7, 563 | 337 | 5, 517 | 2, 383 |
| Nojli | 4. 9346379 | 8, 800 | 7, 600 | 365 | 5, 645 | 2, 320 |
| Dehra | 4. 9346037 | 8, 458 | 6, 917 | 932 | 5, 795 | 2, 254 |
| Mussoorie | 4. 9345569 | 7, 990 | 5, 981 | 2, 875 | 5, 842 | 3, 014 |
| Ismailia | 4. 9346798 | 9, 219 | 8, 439 | 13 | 5, 890 | 2, 562 |
| Meean Meer | 4. 9346729 | 9, 150 | 8. 300 | 294 | 6, 214 | 2, 380 |
| Moré | 4. 9344207 | 6, 628 | 3, 257 | 6, 429 | 6, 836 | 2, 850 |
| Kew | 4. 9340997 | 3, 418 | 6, 837 | 6 | 13, 896 | 2, 947 |

## *Table of residuals.*

| No. | Station. | No. of expedition. | Elevation corr. | Latitude corr. | Logarithm relative gravity. | Same corr. for sea-depth. | *o−c* |
|---|---|---|---|---|---|---|---|
| 1 | Spitzbergen | VII | 9 | 21, 982 | 2, 832 | 2, 657 | + 28 |
| 2 | Melville Island | III | 14 | 21, 129 | 2, 875 | 2, 525 | − 104 |
| 3 | Greenland | VII | 13 | 21, 078 | 2, 485 | ............ | − 144 |
| 4 | Port Bowen | VIII | 49 | 20, 802 | 2, 841 | 2, 666 | + 37 |
| 5 | Hammerfest | VII | 12 | 20, 206 | 2, 420 | ............ | − 209 |
| 6 | Hare Island | II | 18 | 20, 146 | 2, 876 | 2, 526 | − 103 |
| 7 | Kandalachka | IX | 12 | 19, 266 | 2, 666 | ............ | + 37 |
| 8 | Drontheim | VII | 51 | 18, 158 | 2, 237 | ............ | − 392 |
| 9 | Unst | I | 39 | 17, 283 | 2, 741 | ............ | + 112 |
| 10 | Brassa | II | 10 | 17, 081 | 2, 737 | ............ | + 108 |
| 11 | St. Petersburg | IX | 26 | 17, 006 | 2, 808 | ............ | + 179 |
| 12 | Portsoy | I | 39 | 16, 215 | 2, 734 | ............ | + 105 |
| 13 | Sitka (New Archangel) | IX | 6 | 15, 985 | 2, 633 | ............ | + 4 |
| 14 | Leith Fort | I | 28 | 15, 597 | 2, 663 | ............ | + 34 |
| 15 | Altona | XI | 41 | 14, 691 | 2, 642 | ............ | + 13 |
| 16 | Clifton | I | 141 | 14, 659 | 2, 562 | ............ | − 67 |
| 17 | Petropaulowski | IX | 32 | 14, 490 | 2, 956 | ............ | + 327 |
| 18 | Arbury Hill | I | 306 | 14, 184 | 2, 692 | ............ | + 73 |
| 19 | London | I, II, III, IV, V, VI, VII, X, XI, XII, XIII, XIV, XV | 39 | 13, 916 | 2, 571 | ............ | − 58 |
| 20 | Greenwich | VIII, IX, XI, XIII | 66 | 13, 900 | 2, 602 | ............ | − 27 |
| 21 | Kew | XVI | 6 | 13, 896 | 2, 247 | ............ | + 318 |
| 22 | Shanklin Farm | I | 100 | 13, 570 | 2, 572 | ............ | − 57 |
| 23 | Paris | X | 100 | 12, 873 | 2, 445 | ............ | − 184 |
| 24 | New York | VII | 28 | 9, 666 | 2, 553 | ............ | − 76 |
| 25 | Bîr | XIV | 270 | 8, 230 | 2, 372 | ............ | − 257 |
| 26 | Moré | XVI | 6, 429 | 6, 836 | 2, 850 | ............ | + 221 |
| 27 | Meean Meer | XVI | 294 | 6, 214 | 2, 380 | ............ | − 249 |
| 28 | Ismailia | XVI | 13 | 5, 890 | 2, 562 | ............ | − 67 |
| 29 | Bassorah | XIV | 1 | 5, 856 | 2, 630 | ............ | + 1 |
| 30 | Mussoorie | XVI | 2, 875 | 5,842 | 3, 014 | ............ | + 385 |

*Table of residuals*—Continued.

| No. | Station. | No. of expedition. | Elevation corr. | Latitude corr. | Logarithm relative gravity. | Same corr. for sea-depth. | *o*—*c* |
|---|---|---|---|---|---|---|---|
| 31 | Dehra | XVI | 932 | 5, 795 | 2, 254 | .......... | − 375 |
| 32 | Nojli | XVI | 365 | 5, 645 | 2, 320 | .......... | − 309 |
| 33 | Kaliána | XVI | 337 | 5, 517 | 2, 383 | .......... | − 246 |
| 34 | Datairí | XVI | 298 | 5, 254 | 2, 554 | .......... | − 75 |
| 35 | Bonin Island (Port Lloyd) | IX | 6 | 4, 730 | 3, 952 | 3, 252 | + 523 |
| 36 | Usira | XVI | 337 | 4, 670 | 2, 630 | .......... | + 1 |
| 37 | Pahargarh | XVI | 682 | 4, 041 | 2, 573 | .......... | − 56 |
| 38 | Kalianpúr | XVI | 732 | 3, 792 | 2, 796 | .......... | + 167 |
| 39 | Ahmadpúr | XVI | 704 | 3, 638 | 2, 705 | .......... | + 76 |
| 40 | Calcutta | XVI | 8 | 3, 422 | 2, 678 | .......... | + 49 |
| 41 | San Blas de California | IV | 48 | 3, 065 | 2, 249 | .......... | − 380 |
| 42 | Badgaon | XVI | 465 | 2, 852 | 2, 653 | .......... | + 24 |
| 43 | Somtana | XVI | 711 | 2, 430 | 2, 716 | .......... | + 87 |
| 44 | Bombay | XVI | 14 | 2, 385 | 2, 964 | .......... | + 335 |
| 45 | Damargída | XVI | 809 | 2, 184 | 2, 531 | .......... | − 98 |
| 46 | Jamaica | VII | 3 | 2, 156 | 2, 837 | 2, 592 | − 37 |
| 47 | Kodangal | XVI | 796 | 1, 974 | 2, 725 | .......... | + 96 |
| 48 | Cocanáda | XVI | 3 | 1, 931 | 2, 705 | .......... | + 76 |
| 49 | Namthábád | XVI | 487 | 1, 542 | 2, 714 | .......... | + 85 |
| 50 | Guahan | IX | 2 | 1, 228 | 3, 709 | 2, 659 | + 30 |
| 51 | Madras | V, XVI | 11 | 1, 163 | 2, 550 | .......... | − 79 |
| 52 | Bangalore North | XVI | 1, 250 | 1, 165 | 2, 803 | .......... | + 174 |
| 53 | Bangalore South | XVI | 1, 295 | 1, 151 | 2, 782 | .......... | + 153 |
| 54 | Mangalore | XVI | 3 | 1, 126 | 2, 563 | .......... | − 66 |
| 55 | Aden | XVI | 2 | 1, 113 | 2, 858 | .......... | + 229 |
| 56 | Pachapaliam | XVI | 4 | 827 | 2, 197 | .......... | − 432 |
| 57 | Trinidad | VII, VIII | 9 | 776 | 2, 448 | .......... | − 181 |
| 58 | Porto Bello | XIII | 5 | 625 | 3, 156 | .......... | + 527 |
| 59 | Alleppy | XVI | 3 | 619 | 2, 769 | .......... | + 140 |
| 60 | Mallapatti | XVI | 120 | 617 | 2,556 | .......... | − 73 |
| 61 | Sierra Leone | VII | 79 | 496 | 2, 846 | 2, 671 | + 42 |
| 62 | Minicoy | XVI | 3 | 472 | 3, 030 | 2, 855 | + 226 |
| 63 | Kúdankolam | XVI | 70 | 460 | 2, 659 | .......... | + 30 |
| 64 | Punnae | XVI | 20 | 458 | 2, 630 | .......... | + 1 |
| 65 | Port la Coquille (Oualan) | IX | 2 | 199 | 3, 819 | 2, 769 | + 140 |
| 66 | Earl of Abingdon's Island (Gallapagos) | IV | 5 | 2 | 2, 935 | 2, 235 | − 384 |
| 67 | St. Thomas | VII | 9 | 1 | 3, 400 | 2, 350 | − 279 |
| 68 | Para | XIII | 17 | 15 | 2, 554 | .......... | − 75 |
| 69 | Maranham | VII | 32 | 44 | 2,369 | .......... | − 260 |
| 70 | Fernando de Noronha | XIII | 14 | 102 | 3, 608 | 2, 558 | − 71 |
| 71 | Green Mountain | XIII | 926 | 437 | 3, 253 | .......... | + 624 |
| 72 | Ascension | VII, XIII | 7 | 432 | 3, 337 | 2, 637 | + 8 |
| 73 | Bahia | VII | 89 | 1, 149 | 2, 663 | 2, 313 | − 316 |
| 74 | St. Helena | IX, XIII | 14 | 1, 714 | 3, 584 | 2, 884 | + 255 |
| 75 | Rio de Janeiro | IV | 29 | 3, 449 | 2, 438 | .......... | − 191 |
| 76 | Valparaiso | IX | 5 | 6, 757 | 2, 558 | .......... | − 71 |
| 77 | Paramatta | VI | 31 | 7, 038 | 2, 528 | .......... | − 101 |
| 78 | Cape of Good Hope | XII, XIII, XV | 14 | 7, 073 | 2, 607 | .......... | − 22 |
| 79 | Montevideo | XIII | 5 | 7, 456 | 2, 511 | 2, 441 | − 188 |
| 80 | Staten Island | XIII | 7 | 15, 151 | 2, 914 | 2, 739 | + 110 |
| 81 | Cape Horn | XIII | 17 | 15, 550 | 2, 783 | 2, 608 | − 21 |
| 82 | South Shetland | XIII | 10 | 18, 000 | 2, 996 | 2, 821 | + 192 |

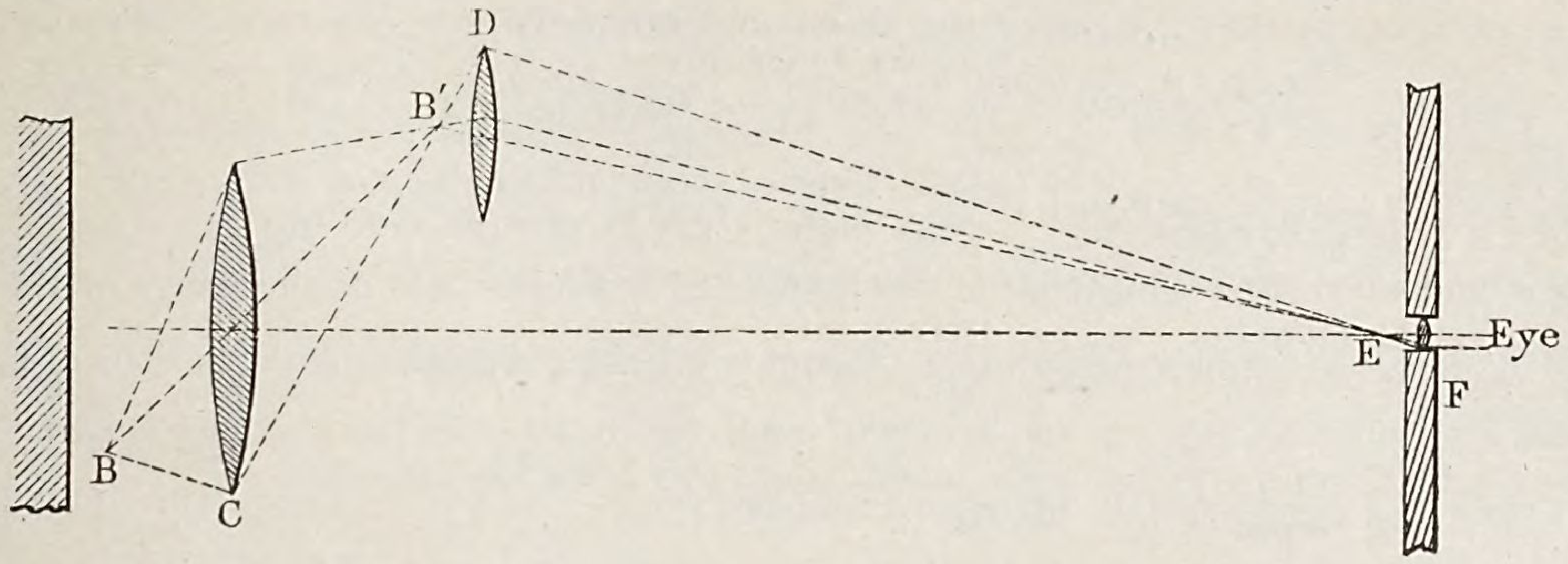
# APPENDIX No. 16.

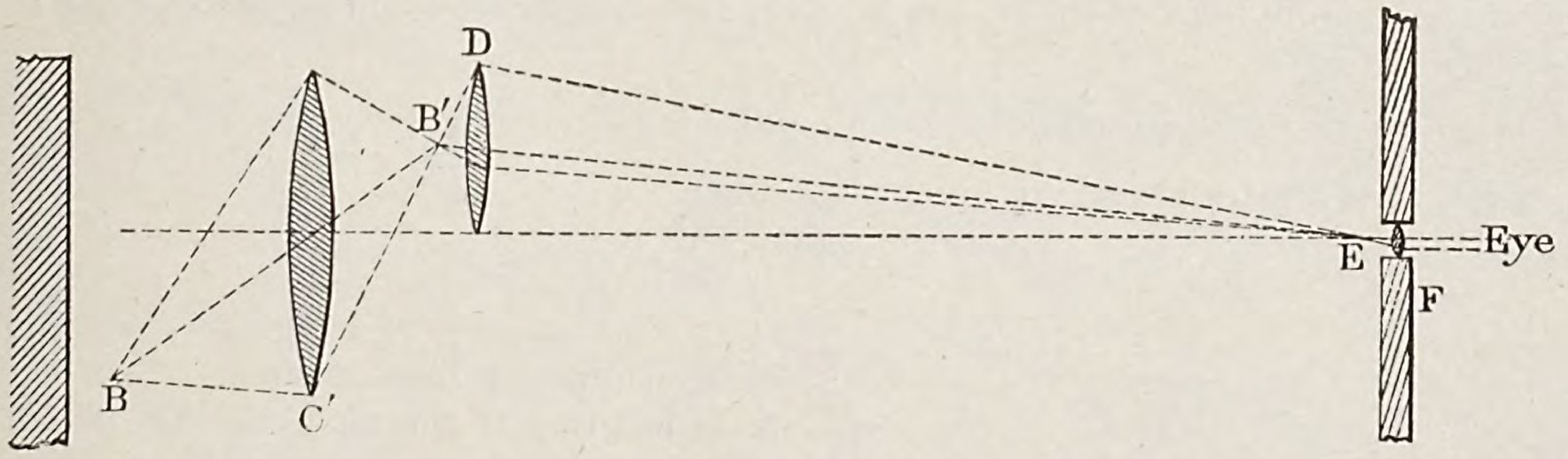
## ON A METHOD OF OBSERVING THE COINCIDENCE OF VIBRATION OF TWO PENDULUMS.

By C. S. PEIRCE, Assistant.

NEW YORK, *August* 2, 1878.

DEAR SIR: I have made a full set of experiments with different methods of observing the coincidences of two pendulums. By far the most accurate method is the following:





To the wall A of a small chamber is fixed a clock which carries on its pendulum a brilliantly illuminated horizontal scale, say of half millimeters. B represents the middle point of this scale. C or C′ is a large achromatic lens placed so that an image of scale will be formed at B′ at a fixed distance from the wall. There are two positions, C and C′, which the lens may have to effect this. In one position the amplitude of vibration of B is multiplied in a certain ratio, say *r;* in the other position it is diminished in the same ratio. This is a well-known optical principle. The lens moves in a slide, by means of strings, and up to stops, so that it can be drawn at any time from one of these positions to the other. At D D is the plane of oscillation of the pendulum on knife-edges, which measures the force of gravity. The plane of motion of D is parallel to that of B. This pendulum carries a lens which brings the image at B′ at focus at E close to the opposite wall F of the room. When the amplitude of D is to the amplitude of B′ as E D is to E B′, the image remains stationary at E, provided the pendulums are in coincidence. The image E is observed by means of an eye-piece, G, fixed in the wall.

The effect is this: The lens C being in the position C (the nearer to B), and the pendulum D oscillating at nearly the right amplitude, the image of the scale will generally flash across the field of vision so rapidly that it can only be seen at the instant of reversing its direction. But as the pendulums approach coincidence it moves less and less, and if the two amplitudes are precisely in the right proportion it finally comes absolutely to rest with the middle of the scale just on the cross-wire of the eye-piece (*i. e.*, just where it would be with the pendulums both at rest). As a general rule, however, it does not come absolutely to rest, but finally gets over, say a millimeter in a second, after which it begins to move faster. The approach to and departure from the minimum amplitude is not very gradual but rather sudden, so that there is no difficulty at all in deciding which is the minimum oscillation. The observer has to note at what second the minimum oscillation occurs, and also what part of the scale is on the cross-wire at the turning points before and after this oscillation; then, by the application of a formula, the time can readily be determined to near $\frac{1}{1000}$th of a second. The lens C is then pulled forward to the position C′, and the observation is repeated when the pendulum has diminished its arc of oscillation sufficiently.

The formula which applies is as follows: Let $s$ be the apparent oscillation of the scale; then,

$$s=a_1 \cos (b_1t+c_1)-a_2 \cos (b_2t+c_2)$$
$$=-(a_1+a_2) \sin \left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right) \sin \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$
$$+(a_1-a_2) \cos \left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right) \cos \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$

Here $a_1$ and $a_2$ are the amplitudes of the knife-edge pendulum and of the image of the other formed at B′ and reduced in the ratio $\frac{\text{ED}}{\text{EB}'}$. $b_1$ and $b_2$ are the reciprocals of the periods of the two oscillations multiplied by 180°; $c_1$ and $c_2$ depend upon the initial conditions. Since $b_1$ and $b_2$ differ very little in value (about $\frac{1}{150}$), it follows that sin and cos $\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)$ go through all their values in about two seconds, while sin and cos $\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$ go through their values in about five minutes. We thus see why the scale should appear to oscillate back and forward in a second with a changing amplitude. If $a_1$ did not change, the amplitude would go through its cycle of changes in five minutes.

Let us see what the amplitude of oscillation of $s$ is for a particular value of $\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}$. Considering this as fixed, the turning takes place when

$$(a_1+a_2) \cos \left(\frac{b_1+b_2}{2}+\frac{c_1+c_2}{2}\right) \sin \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$
$$+(a_1-a_2) \sin \left(\frac{b_1+b_2}{2}+\frac{c_1+c_2}{2}\right) \cos \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)=0$$

Or when

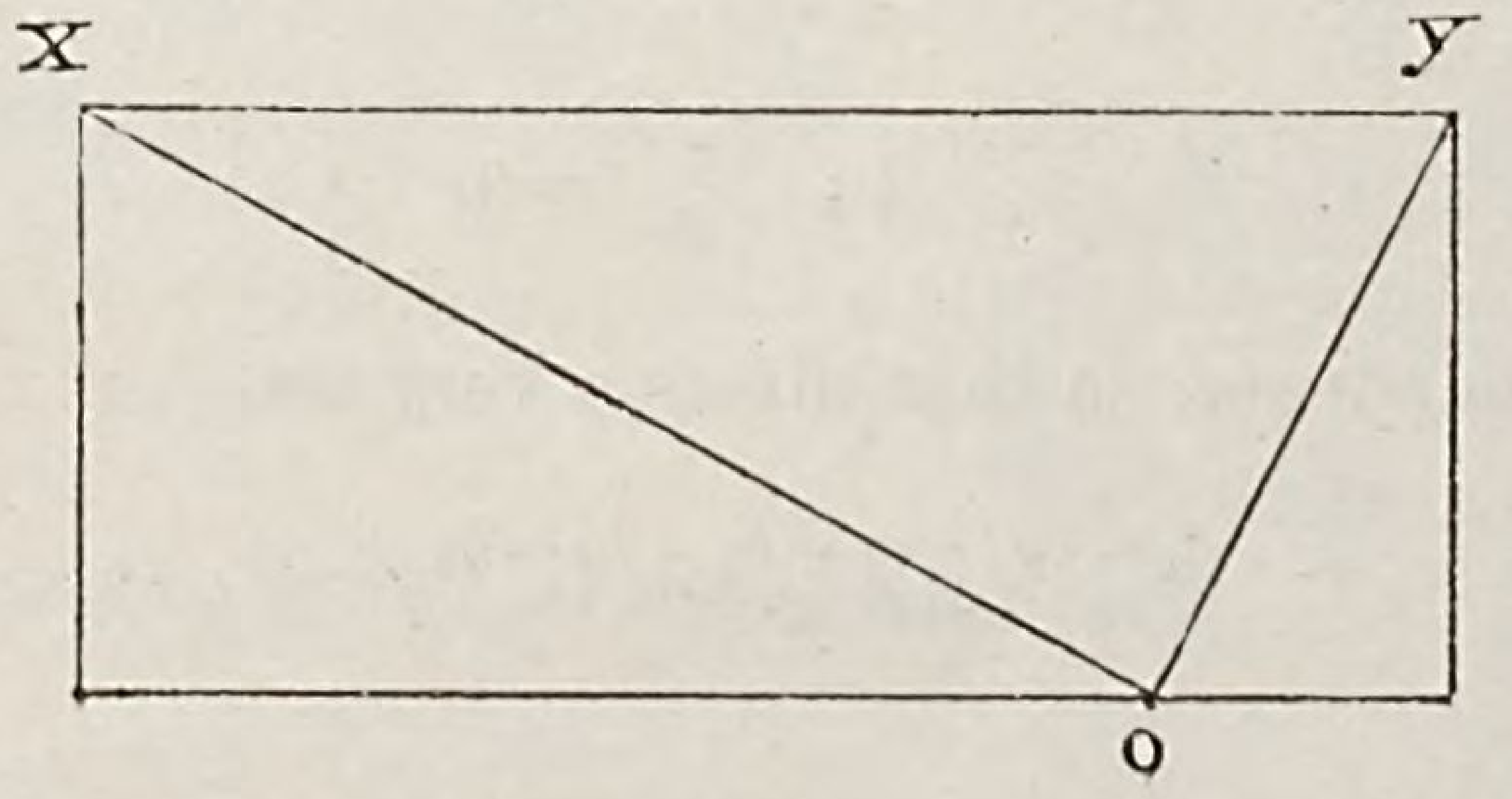
$$-\frac{a_1+a_2}{a_1-a_2} \tan \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)=\tan \left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)$$

Putting in the figure below,

$$\frac{a_1+a_2}{2} \sin \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)=\text{OX}$$

and

$$\frac{a_1-a_2}{2} \cos \left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)=\text{OY}$$



we see that the maximum value of $s$, that is, the value at the turning point, is

$$\sqrt{(\mathrm{OX})^2+(\mathrm{OY})^2}$$

which is

$$\sqrt{(a_1^2+2a_1a_2+a_2^2)\sin^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)+(a_1^2-2a_1a_2+a_2^2)\cos^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}$$

$$=\sqrt{a_1^2+a_2^2-2a_1a_2\cos\left((b_1-b_2)\,t+c_1-c_2\right)}$$

This is the amplitude of the apparent oscillation of the scale. Its greatest value is $a_1+a_2$ and its least value is $a_1-a_2$. A little calculation will show that supposing $a_1$ to be one twenty-fifth part larger than $a_2$, the oscillation next to the smallest has double the amplitude of the smallest. If, therefore, we only sought to know the coincidence within one second (giving the time to $\frac{1}{150}$th of a second) no calculation would be necessary; but we can find the time of coincidence nearer than a second.

For this purpose we require the precise condition which defines the moment of turning. It is

$$\left(-(a_1+a_2)\frac{b_1+b_2}{2}-(a_1-a_2)\frac{b_1-b_2}{2}\right)\cos\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)\sin\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$

$$+\left(-(a_1+a_2)\frac{b_1-b_2}{2}-(a_1-a_2)\frac{b_1+b_2}{2}\right)\sin\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)\cos\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$

$$=-(a_1b_1+a_2b_2)\cos\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)\sin\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$

$$-(a_1b_1-a_2b_2)\sin\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)\cos\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)=0.$$

Hence

$$\tan\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)=-\frac{a_1b_1+a_2b_2}{a_1b_1-a_2b_2}\tan\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)$$

$$\sin\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)=\frac{-\frac{a_1b_1+a_2b_2}{a_1b_1-a_2b_2}\tan\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}{\sqrt{1+\left(\frac{a_1b_1+a_2b_2}{a_1b_1-a_2b_2}\right)^2\tan^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}}$$

$$=\frac{\mp(a_1b_1+a_2b_2)\sin\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}{\sqrt{(a_1b_1-a_2b_2)^2\cos^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)+(a_1b_1+a_2b_2)^2\sin^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}}$$

$$\cos\left(\frac{b_1+b_2}{2}t+\frac{c_1+c_2}{2}\right)=\frac{\pm(a_1b_1-a_1b_2)\cos\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}{\sqrt{(a_1b_1-a_2b_2)^2\cos^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)+(a_1b_1+a_2b_2)^2\sin^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}}$$

Hence

$$s=\pm\frac{(a_1+a_2)(a_1b_1+a_2b_2)\sin^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)\mp(a_1-a_2)(a_1b_1-a_2b_2)\cos^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}{\sqrt{(a_1b_1+a_2b_2)^2\sin^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)+(a_1b_1-a_2b_2)^2\cos^2\left(\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}\right)}}$$

The coincidence occurs when

$$\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}=0.$$

When the turning is near coincidence, so that this is a very small quantity,

$$\frac{b_1-b_2}{2}t+\frac{c_1-c_2}{2}=\frac{b_1-b_2}{2}dt$$

$$s=\pm\frac{(a_1-a_2)(a_1b_1-a_2b_2)+\left\{(a_1+a_2)(a_1b_1+a_2b_2)-(a_1-a_2)(a_1b_1-a_2b_2)\right\}\frac{(b_1-b_2)^2}{4}(dt)^2}{\sqrt{(ab_1-a_2b_2)^2+\left\{(a_1b_1+a_2b_2)^2-(a_1b_1-a_2b_2)^2\right\}\frac{(b_1-b_2)^2}{4}(dt)^2}}$$

$$=\pm\frac{(a_1-a_2)+\frac{1}{2}\frac{a_1a_2(b_1+b_2)}{a_1b_1-a_2b_2}(b_1-b_2)^2(dt)^2}{\sqrt{1+\frac{a_1a_2b_1b_2}{(a_1b_1-a_2b_2)^2}(b_1-b_2)^2(dt)^2}}$$

$$=\pm\left\{a_1-a_2)+\frac{a_1a_2(a_1b_1^2-a_2b_2^2)(b_1-b_2)^2}{(a_1b_1-a_2b_2)^2}(dt)^2\right\}$$

By observing the value of $s$ on the turning points of the smallest oscillation the amplitude will give $(a_1-a_2)$, and the difference of amplitudes on the two sides will give $dt$ to about a sixth of a second on substituting in the last equation the known values of $a_2b_1$ and $b_2$ and the value of $a_1$ determined from the amplitude. This will determine the time to about $\frac{1}{1000}$ of a second.

My opinion, however, is, that the best way of making pendulum observations is with my relay described in my printed paper.

Yours, very respectfully,

C. S. PEIRCE, *Assistant.*

C. P. PATTERSON,
*Superintendent Coast and Geodetic Survey.*

## NOTE.

Since witnessing Major Herschel's experiments, I have done some additional work with the method of coincidences. I have used a scale of half millimeters pasted on the clock pendulum, and brought to focus by a good lens, on the plane of oscillation of the point of a fine cambric needle placed vertically on the gravity pendulum. The correction for decrement of arc—an effect Major Herschel detected and for which Mr. Farquhar has obtained a formula—is considerable in the case of the reversible pendulums. I have read off its value from a diagram constructed for the purpose.

FEBRUARY 20, 1883.

# APPENDIX No. 17.

## ON THE VALUE OF GRAVITY AT PARIS.

By C. S. PEIRCE, Assistant.

The very good agreement between the figures given by Borda and Biot for the value of gravity at Paris, and the quantity found by Kater at London, reduced to Paris by means of the transportation of invariable pendulums, gives us great confidence in the exactness of the result.

The three values for the length of the seconds pendulum are as follows:

| | mm. |
|---|---|
| Borda | 993. 827 |
| Biot | 993. 845 |
| Kater | 993. 867 |

However, it might be supposed that this agreement was merely the result of chance. It is known, in fact, that none of these numbers have received the correction for the inertia of the air drawn along by the pendulum, a correction which was first made by Bessel. Now, it is not necessarily to be supposed, before having made the computations, that this correction should be the same for all three pendulums; Borda's being composed of a platinum ball and an iron wire 4 meters long; Biot's being the same platinum ball, to which was attached a copper wire $0^{m}.6$ long; and that of Kater being made of brass, and irregular in form. But the effect of the atmosphere upon a sphere suspended by a thin cylinder can be exactly calculated by the formulæ which Mr. Stokes has given in his important memoir on this subject. Two elements unite in producing this effect; one arises from simple atmospheric pressure, and the other from that property of the air which the English physicists call *viscosity*, and the Germans *internal friction*. To calculate this last element we must take the value of the viscosity of the air given by modern experiments, those of Maxwell, for instance. Stokes adopted a value for the viscosity much too small. This affects especially the values expressing the effects of the *viscosity* on the suspended wires, and this is why his comparisons between observation and theory do not show the true value of the latter. The atmospheric effect on the caps attaching the platinum ball, and on the sides of the chamber in which the pendulums of Borda and Biot were swung, can be approximately calculated. Of course these corrections are confirmed as well by the observations of the pendulums at different pressures as by analysis.

Biot's observations were also affected by the oscillation of the supports. In regard to the supports used by Borda, according to his description, I believe them to have been very solid, and the correction to be applied to the value of gravity, being inversely proportional to the length of the pendulum employed, must be small in this case. Biot's supports are still at the observatory; however, they have received two modifications: 1st, the sides have been strengthened by two cross-pieces; 2d, the piece which held the pendulum has been replaced by another, which is very solid. With the kind permission of Admiral Mouchez I took off the cross-pieces and measured the flexure of the supports (still provided with the new head), subjected to the effect of a force of 2 kilos. and 5 kilos., applied in a horizontal direction.

The following are the measures—

| | Displacement with 2 kilos. | Displacement with 5 kilos. |
|---|---|---|
| | μ | μ |
| | 13.5 | 34.8 |
| | 12.9 | 34.8 |
| | —— | 35.5 |
| Mean, | 13.2 | 35.6 |
| Per kilo., | 6.6 | 35.2 |
| | | —— |
| Mean, | | 35.2 |
| Per kilo., | | 7.0 |

In order to appreciate the effect produced, not by the large support, but by the little piece which supported the pendulum in Biot's experiments, a careful experimental study will be necessary, aided with the application of a theory entirely different from that which is applicable to elastic supports. For the present I neglect this effect.

Applying the other corrections I get the following numbers:

| | Borda. | Biot. |
|---|---|---|
| Length given | 993827 | 993845 |
| | μ | |
| Hydrodynamic effects | 31.4 | 31.4 |
| Viscosity (sphere) | 35.0 | 23.1 |
| Viscosity wire | 22.6 | 1.8 |
| Effect of caps | 2.1 | 6.2 |
| Effect of sides | 0.2 | 0.2 |
| Flexure (known part) | — | 5.0 |
| Corrected length | 993918.0 | 993913.0 |
| New measure | 993934 | |

If we adopt seven microns as the effect of the unknown part of the flexure of Biot's support, it will be seen that far from weakening our confidence in the exactness of the observations of those illustrious physicists, our corrections only bring into agreement their results. The number expressing the result of my experiments (993.934) differs sensibly from the others. Nevertheless, a careful study of all sources of error has convinced me that it is correct within 10 microns.

The length of the seconds pendulum at Paris, calculated from the experiments of Kater, is $0^{m}.99387$; that is, shorter than my determination by $0^{mm}.07$. If we place confidence in the experiments of General Sabine, made with Kater's pendulum at different pressures, we must add to his measure a correction not less than $0^{mm}.16$, which is two times too great for the agreement of the determinations.

But General Sabine made too few experiments to establish so improbable a result. We can, therefore, assert nothing from the experiments of Kater. In any case, I think, I have sufficiently proved by what precedes, that the number heretofore given for the value of gravity at Paris must be increased by its 1 ten-millionth part.

JUNE 14, 1880.

## NOTE.

In my report upon the Measurement of Gravity at Initial Stations, the unit of measure used is derived from the German Normal Meter No. 49. But Professor Förster has communicated new data with reference to the correction of that bar, in consequence of which it appears that the assumed meter of my publication was 16.6 microns too short. In an article in the American Journal of Science, Vol. XX, October, 1880, it is stated that the United States Office of Weights and Measures makes the same meter 19.2 microns too short. But this statement assumed the committee meter to be correct. According to Barnard and Tresca, however, this meter is 3.4 microns too long. The meter of my paper is, therefore,

By the German comparisons, 16.6
By the American comparisons, 15.8

too short. Applying the mean of these corrections, my value of the seconds' pendulum at Paris becomes $0^{m}.9939175$, which is substantially identical with the value from Borda's corrected experiments, and is probably very close to the correct conclusion from Biot's work.

*Correction.*—On page 432 above, the heading "Dynamical Flexure" is not in the original. This heading correctly describes the experiments, but this phrase was first used later by Professor Plantamour.—[C. S. P.]

# APPENDIX NO. 18.

## REPORT ON A NEW RULE FOR CURRENTS IN DELAWARE BAY AND RIVER.

By HENRY MITCHELL, Assistant Coast and Geodetic Survey, in charge of Physical Hydrography.

BOSTON, *January* 12, 1882.

DEAR SIR: I submit herewith a rule which, I hope, may be of some service to the mariner. The amount of labor it represents is rather more nearly in proportion to this hope than to its real merits, perhaps, but my experience leads me very earnestly to recommend that the *times* of the *currents* (so much more important, usually, than the heights of the tide) should be furnished, if not on our charts, at least in the Coast Pilot, and that this information be in the customary language of seamen.

Hoping that, in its proper form, you will adopt this rule, I am,
Yours, respectfully,

HENRY MITCHELL.

Prof. J. E. HILGARD,
*Superintendent Coast and Geodetic Survey.*

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### *PROPOSED NEW RULE FOR THE CURRENTS OF DELAWARE BAY AND RIVER.*

In all of our harbors and bays subject to tidal influence the presence of landwaters, from rivers or smaller drains, renders the epochs of slackwater variable by irregularly augmenting the ebb-current while diminishing the flood, so that tables embracing these elements are often misleading. In many cases the only epochs that can safely be given to the navigator are those of maximum ebb and maximum flood which are not affected by any landwater supply that can be regarded as constant for six hours.

It would be exceedingly difficult to determine the time of maximum velocity, because of the very gradual change in the rate of movement near the strength of the current, were it not that the curve representing this movement, from slack to slack, is usually symmetrical, and even where this is not the case the *middle time* from the whole curve has been found, from great averages, to fall at maximum.

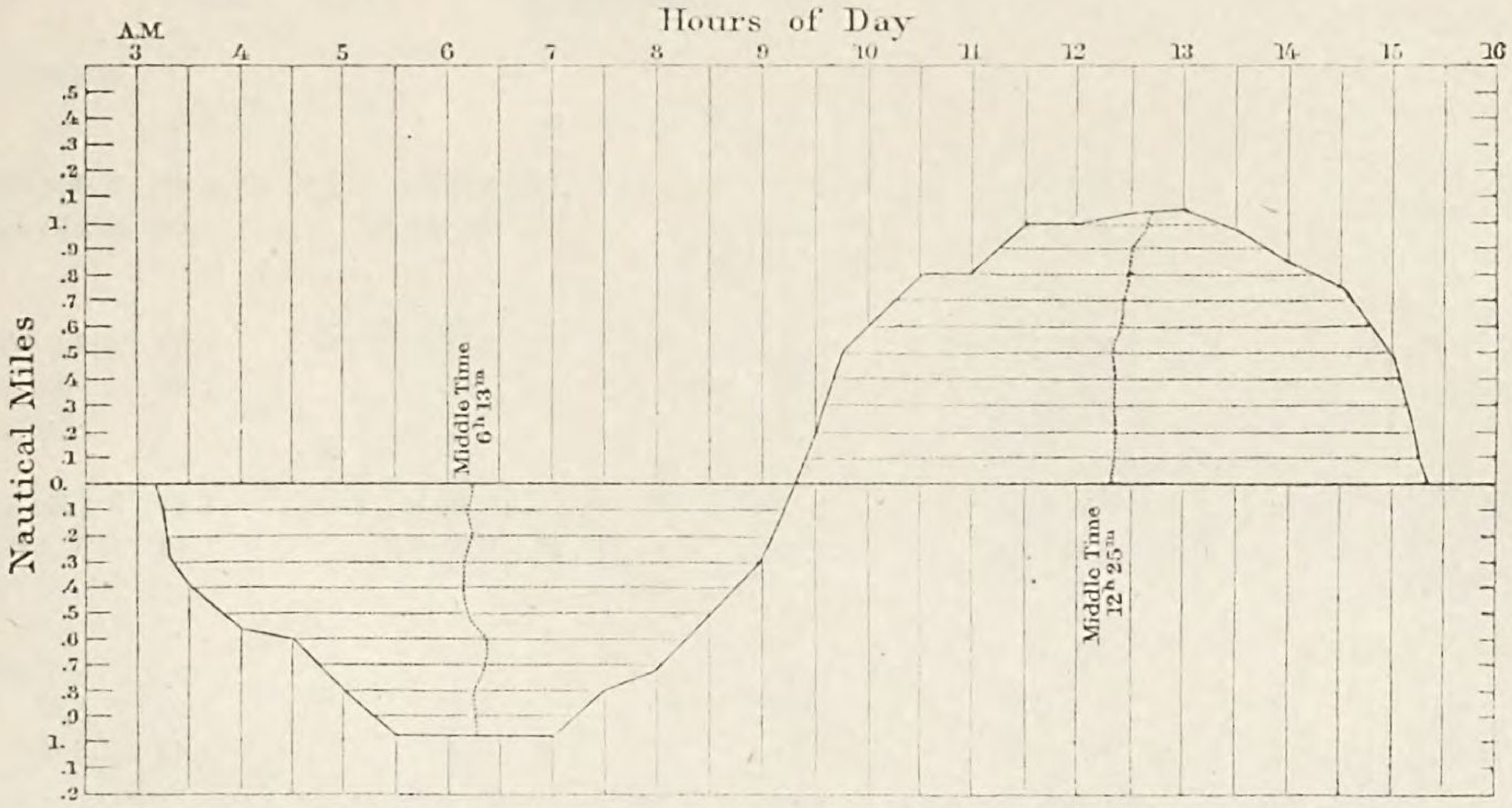
Another advantage in the use of *middle time* lies in the elimination of the *diurnal inequality*—this inequality, as regards interval after moon's transit, having opposite signs at consecutive slacks. Still another advantage lies in the elimination of the effects of steady winds which enter as constants in so short a period as six hours, so as not to affect the time of maximum velocity of current.

Our manner of computing the *middle time* calls into use every observation. We plot these observations upon profile paper, from slack to slack, then draw a line down from the summit of the curve so as to bisect all the chords, and the mean time of this line is the *middle time* sought.

The diagram below, showing actual observations, will serve to make this explanation complete and indicate how each observation is made to contribute to the accuracy of the result.*

*CURRENTS OF DELAWARE BAY, STATION NO. 4, "OUTSIDE OF CAPE HENLOPEN—LIGHT-HOUSE BEARING NEARLY WEST BY COMPASS."*

(Plotted from observations of September 18, 1847, to illustrate the manner of computing middle time.)



In the tables at the close of this report, Mr. J. A. Sullivan, of the Coast and Geodetic Survey, has compiled anew the excellent observations of Lieut. J. R. Goldsborough, made for our service in 1847, to which have been added the new data from Assistant H. L. Marindin's survey of 1877–'78 and 1881. From these tables I gather but one rule that holds good at all seasons; this rule, however, is, I submit, a very useful one.

### RULE.

When the *moon souths* the *ebb-current* at the entrance to Delaware Bay and the *flood-current* at Philadelphia are at their *strength*. At the intermediate reach, known as the "Bight of New Castle," the *strength* of the *flood* occurs three hours *before*, and that of the *ebb* three hours *after* the southing of the moon.

In the above *rule* each of the two clauses presents an antithesis which assists the memory, and the two clauses taken together imply, as they should, progressive change and gradual reversion

At the entrance to the Bay the *rule* applies correctly to the grand channel nearly midway between Cape May and Cape Henlopen, while at Philadelphia its application falls in the neighborhood of Richmond, with a shift either way due to *half-monthly inequality*.

It sometimes happens, when a great freshet occurs in the upper river, that the flood current is obliterated at Philadelphia, but still the *rule* holds good practically, for it predicts the times of greatest and least outflow.

The familiar word "*strength*," which has already been adopted by the Coast and Geodetic Survey to replace the technical term "*middle time*" in the heading of tables for publication, comes in rather awkwardly in the extreme case just mentioned, but it can never deceive.

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*This method first suggested itself to me in connection with the tides and currents of San Francisco Bay, where the *diurnal inequality* is very large. (See Annual Report of Coast Survey 1870, pages 42 and 43.)

## CURRENTS OF DELAWARE BAY.

[These data have been corrected for mean rise or fall of tide, and "*Strength*" is the term adopted by the Coast and Geodetic Survey as the synonym of "*Middle Time*."]

| Locality of station. | Time of turning after moon's transit. |  | First quarter. |  | Strength. |  |  |  | Third quarter. |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  | Flood to ebb. | Ebb to flood. | Set. | Drift. | Time after moon's transit. |  | Set. | Drift. | Set. | Drift. |
| GROUP I. | *h. m.* | *h. m.* |  | *Knots.* | *h. m.* | *h. m.* |  | *Knots.* |  | *Knots.* |
| No. 1, August 21, 1847: "Abreast of Brandywine Shoal, 1 mile West of Center." | ........ | 3 41 | NW. by N. ½ N. | 1.32 | ........ | 6 12 | NW. by N. ¾ N.. | 1.64 | N. by W. ¾ W... | 0.96 |
|  | 9 46 | ........ | SE. ½ S.......... | 1.20 | 0 17 | ........ | SE. by S........ | 1.40 | SE. by S. ½ S.... | 1.12 |
|  | ........ | 3 35 | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 2, August 17, 1847: "1 mile East of the Buoy on the Brown." | ....... | 3 17 | NW. by N. ¾ N.. | 1.34 | ........ | 6 07 | N. by W. ¼ W... | 1.65 | N. by W ........ | 1.41 |
|  | 9 32 | ........ | SE. by S. ¾ S .... | 1.21 | 0 38 | ........ | SSE ............ | 1.85 | S. ¾ E .......... | 1.21 |
|  | ........ | 3 50 | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 18, August 20, 21, 1847: "1½ miles West of the Brown Buoy bearing East." | 10 19 | ....... | SE. by S ...... | 1.19 | 1 10 | ........ | S. by E. ¼ E ..... | 1.40 | S. ¾ E .......... | 1.21 |
|  | ........ | 4 18 | NW. ¾ N ....... | 1.31 | ........ | 6 25 | NW. ¾ N....... | 1.59 | NW. by N. ½ N.. | 1.28 |
|  | 9 58 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 17, August 16, 1847: "Entrance to New England Channel." | 8 51 | ........ | S. ¾ E.......... | 1.41 | B. T. 0 23 | ........ | S. ¼ W ......... | 1.81 | S. ¼ W ......... | 1.30 |
|  | ........ | 3 09 | N. by W....... | 1.23 | ........ | 5 26 | N. ½ E.......... | 1.43 | N. ½ E.......... | 1.28 |
|  | 8 24 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| Mean of Group I, Nos. 1, 2, 18, 17. | ........ | 3 38 | ................ | ....... | ........ | 6 02 | ................ | ....... | ................ | ...... |
|  | 9 28 | ........ | ................ | ....... | A. T. 0 25 | ........ | ................ | ....... | ................ | ...... |
| GROUP II. |  |  |  |  |  |  |  |  |  |  |
| No. 3, September 9, 1847: "In the Main Ship Channel Cape Henlopen Light-House, bearing SSW." | 9 05 | ........ | South.......... | 1.51 | B. T. 0 38 | ........ | SE. ½ S......... | 1.96 | SE. by S. ¾ S .... | 1.34 |
|  | ........ | 2 54 | W. by N........ | 1.36 | ........ | 5 50 | WNW...... ... | 1.90 | W. by N. ¼ N .... | 1.51 |
|  | 9 19 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 4, September 18, 1847: "Outside of Cape Henlopen Light-House, bearing nearly West by compass." | 9 11 | ........ | S. ½ W .......... | 1.12 | A. T. 0 09 | ........ | South.......... | 1.48 | SE. by S. ¼ S .... | 1.12 |
|  | ........ | 2 54 | NW. ¾ W..... . | 0.93 | ........ | 5 50 | NW. by W. ¼ W. | 1.18 | NW. by W. ¼ W. | 1.00 |
|  | 8 54 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| Mean of Group II, Nos. 3, 4. | 9 07 | ........ | ................ | ....... | B. T. 0 15 | ........ | ................ | ....... | ................ | ...... |
|  | ........ | 2 54 | ................ | ....... | ........ | 5 50 | ................ | ....... | ................ | ...... |
| GROUP III. |  |  |  |  |  |  |  |  |  |  |
| No. 7, September 15, 16, 1847: "2 miles North of McCries Shoal." | 8 24 | ........ | E. ½ N.......... | 1.20 | B. T. 1 05 | ........ | E. ½ N.......... | 1.22 | E. ¼ N.......... | 0.90 |
|  | ........ | 2 51 | W. ¼ S .......... | 0.88 | ........ | 5 16 | West .......... | 1.39 | W. ¾ S .......... | 0.85 |
|  | 8 16 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 20, September 17, 1847: "5 miles from coast off Hereford Inlet." | ........ | 2 31 | NW. ¼ N........ | 0.53 | ........ | 5 28 | NW. ¾ W ....... | 0.58 | NW. ¼ W ...... | 0.58 |
|  | 8 26 | ........ | NE. by N. ½ N... | 1.17 | B. T. 1 06 | ........ | NE. by N ....... | 1.27 | NE. by N. ¾ N... | 0.91 |
|  | ........ | 2 26 | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| Mean of Group III, Nos. 7, 20. | 8 22 | ........ | ................ | ....... | B. T. 1 05 | ........ | ................ | ....... | ................ | ...... |
|  | ........ | 2 26 | ................ | ....... | ........ | 5 22 | ................ | ....... | ................ | ...... |
| No. 5, September 28, 29, 1847: "5 miles SE. of S. Spit of 'Hen and Chicken' Shoal." | ........ | 3 16 | No data......... | 0.92 | ........ | 6 28 | No data......... | 1.11 | No data......... | 0.86 |
|  | 9 21 | ........ | ....do .......... | 0.72 | 0 53 | ........ | ....do .......... | 1.20 | ................ | 0.86 |
|  | ........ | 3 08 | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |
| No. 6, September 16, 1847: "2 miles South of McCries Shoal." | 8 26 | ........ | E. by S.......... | 1.01 | B. T. 0 32 | ........ | E. ¾ S.......... | 1.25 | East............ | 0.88 |
|  | ........ | 2 42 | W. ¼ N.......... | 1.28 | ........ | 4 54 | W. ½ N.......... | 1.42 | W. ¼ N.......... | 0.85 |
|  | 8 22 | ........ | ................ | ....... | ........ | ........ | ................ | ....... | ................ | ...... |

## CURRENTS OF DELAWARE BAY—Continued.

[These data have been corrected for mean rise or fall of tide, and "*Strength*" is the term adopted by the Coast and Geodetic Survey as the synonym of "*Middle Time*."]

| Locality of station. | Time of turning after moon's transit. | | First quarter. | | Strength. | | | | Third quarter. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Flood to ebb. | Ebb to flood. | Set. | Drift. | Time after moon's transit. | | Set. | Drift. | Set. | Drift. |
| **Group III**—Continued. | *h. m.* | *h. m.* | | *Knots.* | *h. m.* | *h. m.* | | *Knots.* | | *Knots.* |
| No. 19, August 19, 20, 1847: | 8 29 | ........ | SE. by E. ¾ E... | 0.84 | B. T.<br>1 29 | ........ | SE. by E. ½ E.... | 0.96 | SE. ½ E.......... | 0.50 |
| "Near the tail of the | ........ | 1 58 | W. by N. ½ N... | 1.29 | ........ | 4 43 | NW. ½ W ....... | 1.49 | NW. ¼ W ....... | 0.95 |
| Shears." | 8 45 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 16, August 14, 15, 1847: | ........ | 2 39 | NE. ½ E ........ | 1.31 | ........ | 4 44 | NE. ½ E......... | 1.44 | NE. ¾ N.......... | 0.85 |
| "In Cape May Roads." | 7 54 | ........ | S. ¾ W ......... | 1.64 | B. T.<br>1 40 | ........ | S. ¼ W .......... | 1.94 | S. ¼ E ........... | 1.09 |
| (Not reduced for tide.) | ........ | 2 03 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| **Group IV.** | | | | | | | | | | |
| No. 8, September 8, 1847: | ........ | 2 47 | NW. by W. ¾ W. | 1.25 | ........ | 5 01 | NW. by W. ¾ W | 1.32 | WNW........... | 0.85 |
| "Southern Channel through the Overfalls." | 9 14 | ........ | E. ¾ S.......... | 1.28 | B. T.<br>0 34 | ........ | E. ½ S ........... | 1.78 | E. ½ S ........... | 1.28 |
| | ........ | 2 45 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 9, September 7, 1847: | 9 14 | ........ | SSE ............ | 1.61 | B. T.<br>0 38 | ........ | SE. by S ........ | 2.04 | SE. by S. ½ S .... | 1.26 |
| "Southern Channel | ........ | 2 33 | NW. by W. ½ W. | 1.61 | ........ | 5 16 | NW. by W. ½ W. | 2.03 | NW. by W. ¼ W. | 1.33 |
| through the Overfalls." | 9 06 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 10, September 6, 1847: | ........ | 2 47 | W. ¾ N.......... | 1.37 | ........ | 5 09 | W. by N. ¼ N.... | 1.74 | W. by N. ¼ N.... | 1.12 |
| "Northern Channel through the Overfalls." | 9 17 | ........ | SE. by E. ½ E.... | 1.73 | B. T.<br>0 42 | ........ | SE. by E. ½ E... | 2.04 | SE. by E. ½ E.... | 1.18 |
| | ........ | 3 09 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 11, August 27, 1847: | 8 35 | ........ | SE. by E. ¼ E.... | 1.64 | B. T.<br>0 24 | ........ | SE. by E ........ | 2.09 | SE. by E. ¼ E.... | 1.29 |
| "Northern Channel | ........ | 2 42 | N. by W. ¾ W ... | 1.75 | ........ | 5 45 | NW. ¾ N... .... | 2.12 | NW. ¼ N........ | 1.66 |
| through the Overfalls." | 8 42 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 12, August 24, 25, 1847: | ........ | 2 30 | NW ............ | 0.90 | ........ | 4 58 | NW. ¾ W ....... | 1.11 | NW. ¼ W ....... | 0.78 |
| "Northern Channel through the Overfalls." | 8 42 | ........ | SE. by S ........ | 1.21 | B. T.<br>0 40 | ........ | SE. by S ........ | 1.33 | SE. by S. ½ S..... | 0.99 |
| | ........ | 2 42 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 13, August 26, 1847: | 8 36 | ........ | E. by S. ¼ S...... | 1.20 | B. T.<br>0 41 | ........ | E. ¾ S ........... | 1.56 | E. by S.......... | 1.00 |
| "In the Coaster's Chan- | ........ | 2 10 | W. by N. ¼ N.... | 1.15 | ........ | 5 10 | W. ½ N.......... | 1.40 | W. ¼ N.......... | 0.91 |
| nel around Cape May." | 8 48 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 14, August 25, 1847: | 8 27 | ........ | SSE ............ | 1.25 | B. T.<br>1 13 | ........ | S. by E. ½ E...... | 1.57 | S. ½ E ........... | 1.00 |
| "In the Channel over | ........ | 2 04 | NW. ½ N........ | 1.16 | ........ | 5 18 | NW. by N ...... | 1.41 | NW. by N. ¼ N .. | 1.05 |
| Ridges of Cape May." | 8 34 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| No. 15, August 23, 24, 1847: | 8 57 | ........ | SW. by S. ¾ S.... | 0.86 | B. T.<br>0 39 | ........ | S. ¾ W .......... | 1.04 | S. ¾ W .......... | 0.89 |
| "In the Channel over | ........ | 3 04 | N. ½ W.......... | 1.09 | ........ | 4 46 | N. by W ........ | 1.24 | N. by W ........ | 0.81 |
| Ridges of Cape May." | 8 29 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| Mean of Group IV, Nos. 8, | 8 49 | ........ | ........ | ........ | B. T.<br>0 41 | ........ | ........ | ........ | ........ | ........ |
| 9, 10, 11, 12, 13, 14, 15. | ........ | 2 39 | ........ | ........ | ........ | 5 10 | ........ | ........ | ........ | ........ |

## CURRENTS OF DELAWARE RIVER.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | ........ | 9 24 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| | 3 04 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| November 16, 17, 18, 1877: | ........ | 9 44 | Up river........ | 1.01 | 0 22 | ........ | Up river........ | 1.47 | Up river........ | 1.21 |
| Fathomer No. 1, "Off 5 | 3 06 | ........ | Down river ..... | 1.75 | ........ | 6 35 | Down river ..... | 1.84 | Down river.... | 1.50 |
| Mile Point, mid stream." | ........ | 10 26 | Up river........ | 1.33 | 0 23 | ........ | Up river........ | 1.55 | Up river........ | 1.15 |
| | 3 09 | ........ | Down river ..... | 1.60 | ........ | 6 40 | Down river..... | 1.67 | Down river..... | 1.50 |
| | ........ | 10 20 | ........ | ........ | ........ | ........ | ........ | ........ | ........ | ........ |
| Mean Fathomer No. 1 .... | ........ | 9 59 | ........ | ........ | 0 23 | ........ | ........ | ........ | ........ | ........ |
| | 3 06 | ........ | ........ | ........ | ........ | 6 38 | ........ | ........ | ........ | ........ |

DELAWARE RIVER.

| Locality. | Number of tides observed. | Mean interval before or after transit. | | Number of tides observed. | Mean interval before or after transit. | | Remarks. |
|---|---|---|---|---|---|---|---|
| | | High water. | Slack, flood to ebb. | | Low water. | Slack, ebb to flood. | |
| | | h. m. | h. m. | | h. m. | h. m. | |
| Five Mile Point | H. W. 6<br>Slack 3 | 1 48 | 3 06 | L.W. 7<br>Slack 3 | 9 12 | 9 59 | Observed in 1877. |
| Kensington | H.W.35<br>Slack 26 | 1 22 | 2 29 | L.W. 28<br>Slack 30 | 8 52 | 9 19 | Observed in 1878. |
| Old Navy Yard | H.W.84<br>Slack 63 | 1 12 | 2 15 | L.W. 93<br>Slack 78 | 8 30 | 9 00 | Observed in 1877. |
| League Island | H.W.11<br>Slack 3 | 0 53 | 1 50 | L.W. 10<br>Slack 2 | 8 08 | 8 40 | Observed in 1877–'81. |
| Billingsport | H.W.16<br>Slack 7 | 0 42 | 1 30 | L.W. 16<br>Slack 7 | 8 13 | 9 00 | Observed in 1881. |
| Marcus Hook | H.W. 9<br>Slack 10 | –0 27 | 0 25 | L.W. 9<br>Slack 8 | 7 16 | 7 50 | Do. |
| Bellevue | H.W. 7<br>Slack 4 | –0 43 | 0 20 | L.W. 6<br>Slack 3 | 6 44 | 7 28 | Do. |
| New Castle | H.W. 5<br>Slack 3 | –0 57 | 0 27 | L.W. 5<br>Slack 5 | 6 02 | 6 55 | Do. |
| Fort Delaware | H.W. 3<br>Slack 1 | –1 09 | –1 26 | L.W. 3<br>Slack 3 | 5 41 | 6 18 | Do. |
| Delaware City | H.W. 3<br>Slack 4 | –1 16 | –0 13 | L.W. 7<br>Slack 7 | 5 40 | 6 47 | Do. Doubtful. |
| Port Penn | H.W. 8<br>Slack 3 | –1 39 | –0 38 | L.W. 6<br>Slack 4 | 5 04 | 5 24 | Do. |
| Reedy Island Light-House | H.W. 1 | –1 22 | ........ | ............ | ........ | ........ | Do. |

The sign – denotes that the interval is *before* the transit.

## NOTE.

*Relative to the times of high and low water in Delaware Bay and River.*

It has seemed to me that in the case of a long arm of the sea like Delaware Bay, it would be better to write across the face of the chart the times of the tide in proper location, rather than to give these times in a separate table for points where acutally observed, provided we could get enough data to determine the law of tidal propagation.

At your request Capt. Wm. Ludlow, United States Engineer in charge of the improvements in Delaware Bay, sent to me the tidal observations that he had caused to be made, and which had been referred to the breakwater as a standard station. These observations, when plotted for time and distance, gave such smooth curves that I wrote to Captain Ludlow inquiring if any formula for adjustment had been applied. He replied that there had not, and that the only liberty taken had been to refer any station of brief occupation to the next one above and below and balance the differences. This was before any careful table of distances had been made out.

I give below the observations as furnished, with two additional columns containing the elements of the best fitting parabolic curves. These curves furnish the law of propagation in the sense that I have employed the phrase before, but in no wider sense than a local rule for interpolation. The formulæ used are $y = 2.2\,x + 0.018\,x^2$ and $y^1 = 3.4\,x + 0.018\,x^2$, in which $y$ is the time of high and $y^1$ the time of low water respectively, while $x$ is the distance from the breakwater in nautical miles, measured along the channel-way.

I never before have seen observations of natural phenomena fitting so perfectly to a simple theory. It seems to me that here we have a case where local names can be dispensed with, and the times placed on the chart at equi-distant points without fear of error.

The true *establishments* of the breakwater have not yet been computed.

## PROGRESS OF TIDE IN DELAWARE BAY AND RIVER.

| Number of data. | Distances, in nautical miles. | Localities. | Observed time of high water. | Curve by formula. | Difference of observed and computed times. | Observed time of low water. | Curve by formula. | Difference of observed and computed times. |
|---|---|---|---|---|---|---|---|---|
| | | | *Minutes.* | | *Minutes.* | *Minutes.* | | *Minutes.* |
| 659 | 0 | Breakwater | 0 | 0 | .......... | 0 | 0 | .......... |
| 20 | 42.1 | Collins' Beach | 125 | $124\frac{1}{2}$ | $0\frac{1}{2}$ | 167 | 175 | 8 |
| 28 | 49.4 | Port Penn | 151 | $152\frac{1}{2}$ | $1\frac{1}{2}$ | 210 | 212 | 2 |
| 17 | 54.2 | Fort Delaware | 171 | 172 | 1 | 237 | 237 | 0 |
| 21 | 58.9 | New Castle | 191 | 189 | 2 | 264 | $262\frac{7}{10}$ | $1\frac{1}{2}$ |
| 21 | 61.9 | Pigeon Point | 206 | 205 | 1 | 285 | $279\frac{4}{10}$ | $5\frac{1}{2}$ |
| 127 | 64.7 | Edgemoor | 216 | $217\frac{1}{2}$ | $1\frac{1}{2}$ | 297 | 295 | 2 |
| 109 | 70.4 | Marcus Hook | 243 | 244 | 1 | 330 | $328\frac{6}{10}$ | $1\frac{1}{2}$ |
| 6 | 73.7 | Chester | 259 | 260 | 1 | 350 | 348 | 2 |
| 38 | 79.0 | Billingsport | 284 | 286 | 2 | 378 | 381 | 3 |
| 104 | 80.9 | Fort Mifflin | 296 | $295\frac{8}{10}$ | 0 | 391 | 393 | 2 |
| 23 | 92.1 | Five-mile Point | 356 | 355 | 1 | 461 | $465\frac{8}{10}$ | 5 |
| 13 | 112.4 | Bordentown | 483 | $474\frac{7}{10}$ | $8\frac{1}{2}$ | 605 | $609\frac{1}{2}$ | $4\frac{1}{2}$ |

HENRY MITCHELL.

# LIST OF SKETCHES.

No. 1. Map of general progress (eastern part).
2. Map of general progress (western part).
3. Section I. Northern part.
4. Section I. Southern part, with Lake Champlain.
5. Sections I and II. Primary triangulation between the Hudson and St. Croix Rivers.
5ª. Sections I and II. Primary triangulation between Fire Island Base and Lake Ontario.
6. Section II. Point Judith to New York City.
6ª. Section II. New York City to Cape Henlopen.
7. Sections II and III. Primary triangulation between Long Island and the Blue Ridge.
7ª. Section II. Reconnaissance and triangulation in Pennsylvania and New Jersey.
8. Section III. Chesapeake Bay and tributaries.
9. Section IV. Coast and Sounds of North Carolina.
10. Sections III and IV. Primary triangulation between the Maryland and Georgia base-lines (northern part).
11. Sections III, IV, and V. Primary triangulation between the Maryland and Georgia base-lines (southern part).
12. Section V. Coasts of South Carolina and Georgia.
13. Section VI. East Coast of Florida, Amelia Island to Halifax River.
14. Section VI. East Coast of Florida, Halifax River to Cape Canaveral.
15. Section VI. East Coast of Florida, Halifax and Indian Rivers.
16. Section VI. West Coast of Florida, Charlotte Harbor to Anclote Keys.
17. Section VII. West Coast of Florida, Anclote Keys to Perdido Bay.
18. Section VIII. Alabama, Mississippi, and Louisiana.
19. Section VIII. Triangulation of Mississippi River.
20. Section IX. Texas.
21. Gulf of Mexico and Caribbean Sea.
22. Section X (lower sheet). Coast of California from San Diego to Point Sal.
23. Section X (middle sheet). Coast of California from Point Sal to Tomales Bay.
24. Section X (upper sheet). Coast of California from Tomales Bay to the Oregon line, and
Section XI (lower sheet). Coast of Oregon from the California line to Tillamook Bay.
25. Section XI (upper sheet). Coasts of Oregon and Washington Territory from Tillamook Bay to the boundary.
26. Sections XIII and XIV. Reconnaissance and triangulation in Kentucky and Indiana.
27. Section XIII. Reconnaissance and triangulation in Tennessee.
27ª. Section XIV. Reconnaissance and triangulation in Ohio.
28. Section XIV. Reconnaissance and triangulation in Wisconsin.
29. Sections XIV and XV. Geodetic connection of the Atlantic and Pacific coast triangulation, Missouri and Illinois.
30. Section XVI. Geodetic connection of the Atlantic and Pacific coast triangulation, Nevada.
31. Chart showing positions of magnetic stations in the United States.
32. Chart showing positions of longitude stations in the United States.

## ILLUSTRATIONS.

No. 33. To Appendix No. 7. Topography of The Dalles.
34. To Appendix No. 8. Magnetometer.
35. To Appendix No. 8. Theodolite magnetometer.
36. To Appendix No. 8. Alt-azimuth and magnetometer.
37. To Appendix No. 8. Dip-circle.
38. To Appendix No. 10. Illustrating papers on meteorological researches.
39. To Appendix No. 11. Showing oyster growth.
40. To Appendix No. 11. Showing oyster growth.
41. To Appendix No. 11. Showing oyster growth.
42. To Appendix No. 11. Showing oyster growth.
43. To Appendix No. 11. Showing oyster growth.
44. To Appendix No. 11. Showing oyster growth.
45. To Appendix No. 11. Sketch showing limits of oyster beds, James River.
46. To Appendix No. 11. Sketch showing limits of oyster beds, upper part of Tangier Sound.
47. To Appendix No. 11. Sketch showing limits of oyster beds, lower part of Tangier Sound and Pocomoke Sound.
48. To Appendix No. 11. Profiles of bottom, Tangier Sound.
49. To Appendix No. 11. Profiles of bottom, Tangier Sound.
50. To Appendix No. 11. Profiles of bottom, Tangier Sound.
51. To Appendix No. 11. Profiles of bottom, Tangier Sound.
52. To Appendix No. 11. Profiles of bottom, Tangier Sound.
53. To Appendix No. 11. Profiles of bottom, Tangier Sound.
54. To Appendix No. 11. Profiles of bottom, Pocomoke Sound.
55. To Appendix No. 11. Temperature curves, Tangier Sound.
56. To Appendix No. 11. Density of water curves, Tangier Sound.
57. To Appendix No. 11. Density of water curves, Tangier Sound.
58. To Appendix No. 11. Density of water curves, Tangier and Pocomoke Sounds.
59. To Appendix No. 11. Density of water curves, Pocomoke Sound and mouth of Pocomoke River.
60. To Appendix No. 11. Curves showing monthly change of mean density at spring tides, Tangier and Pocomoke Sounds.
61. To Appendix No. 11. Curves showing monthly change in mean density in Tangier and Pocomoke Sounds.
62. To Appendix No. 11. Curves showing difference of density at the bottom, at the head of and entrance to Tangier Sound.
63. To Appendix No. 11. Drawing of the Astyris.

85°

No. 3

PLATE No. 893

(Upper Sheet)

UNITED STATES

COAST AND GEODETIC SURVEY

Sketch

Showing the progress of the Survey in

SECTION No. 1

From 1852 to 1881

Scale $\frac{1}{400,000}$

June 30, 1881

NOTES

A. Signifies Astronomical Station
M.....do......Magnetic............do....
T.....do......Tidal..................do....
X.....do.......Current..............do....
.....do.......observed lines between principal Stations of the primary triangulation
.....do..........do.................do......subsidiary Stations of the primary triangulation
.....do..........do.................do......Stations of the Secondary triangulation
Broken lines signify that they have not been observed from the Stations near which they are so shown.
Tertiary triangulation points are indicated thus ᵹ the lines to them are omitted to avoid confusion
▨ Surveyed Topography
░ .....do......Hydrography
Heavy shore line surveyed
Faint shore line unsurveyed

Rocks off
PORTLAND HARBOR
Surveyed in 1864
Scale $\frac{1}{200,000}$

RECONNOISSANCE
For connecting the Survey of the Coast
with the N.E. Boundary Survey
Scale $\frac{1}{600,000}$
1867

No. 5a

UNITED STATES
COAST AND GEODETIC SURVEY

---

PRIMARY TRIANGULATION
between the
MASSACHUSETTS BASE AND LAKE ONTARIO

Scale $\frac{1}{1000000}$

June 30, 1881

Note
——— *signifies Lines between occupied Stations*
—— – – – *" " " " and unoccupied Stations*
– – – – – – *" " " unoccupied Stations*

Note. *One kilometer or 1000 meters = 3280.87 ft. = $\frac{5}{8}$ of a statute mile nearly. One statute mile = 1609.33 meters*

No. 6

PLATE No. 57

UNITED STATES

COAST AND GEODETIC SURVEY

Sketch

*Showing the*

*TRIANGULATION & GEOGRAPHICAL POSITIONS*

*IN*

*SECTION No. II*

*From New York City to Point Judith*

*Scale* $\frac{1}{400\,000}$

*June 30, 1881*

NOTE

*A complete resurvey of New York Bay and Harbor, both topographic and hydrographic, was made in 1855 '57 The Channels have been sounded frequently since. A resurvey of the shoreline and wharves of New York Harbor was made in 1875.*

——— Signifies Lines between primary occupied stations
——— *do* — *do* — *do* — *secondary* — *do* — *do*

| | | | | | |
|---|---|---|---|---|---|
| *Ch.* | *do.* | *Church* | * | *Signifies* | *Light House* |
| *Ho.* | *do.* | *House* | ‡ | *do.* | *Cupola or Spire* |
| *H.* | *do.* | *Hill* | ⚐ | *do.* | *Signal* |
| *N.* | *do.* | *Neck* | | | |

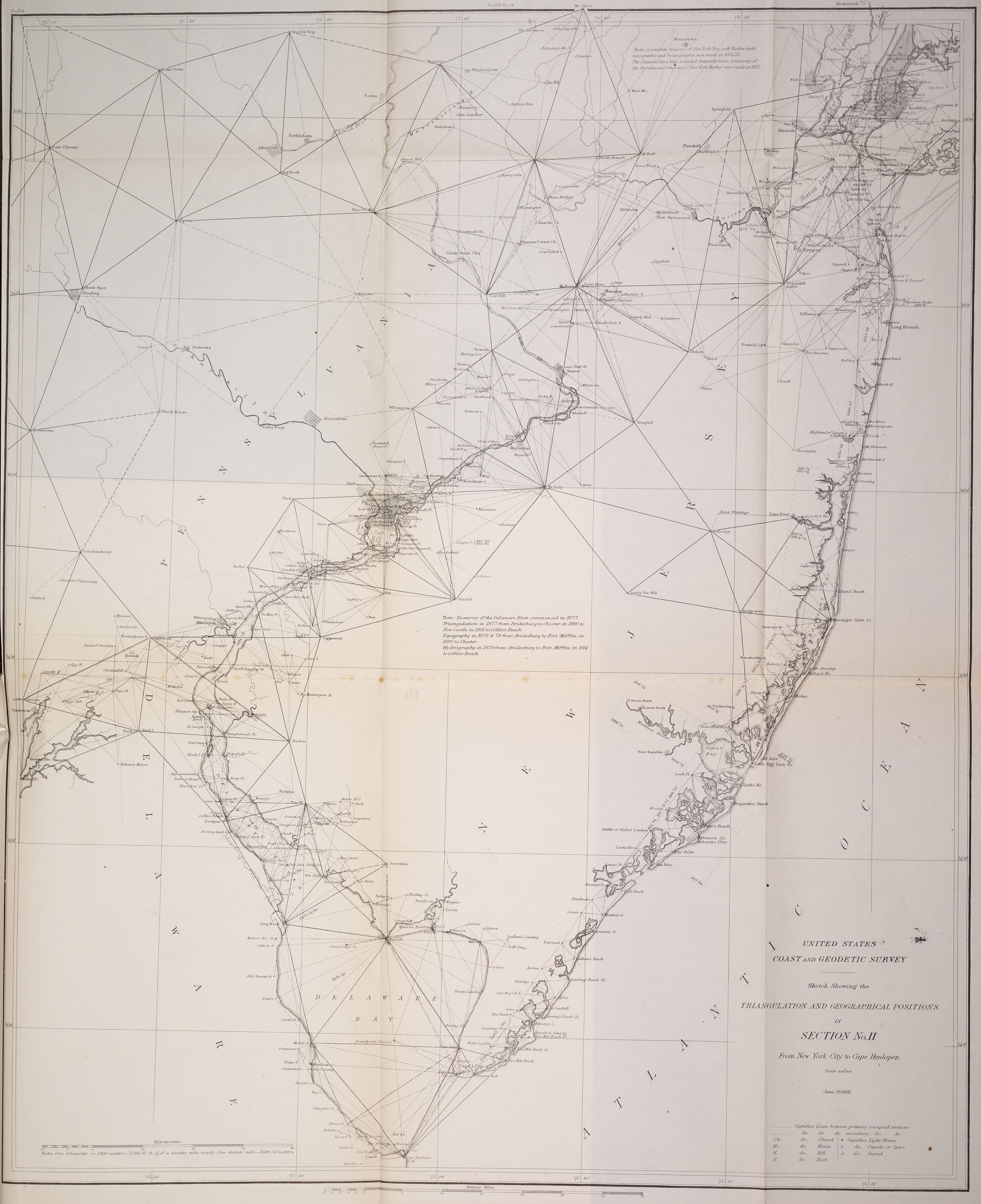
Kilometers

10 5 0 10 20 30 40

Note. *One kilometer or 1000 meters = 3280.87 ft. = ⅝ of a statute mile nearly. One statute mile = 1609.33 meters.*

No. 6 a

PLATE No. 18



Note. A complete resurvey of New York Bay and Harbor; both topographic and hydrographic, was made in 1855-'57. The Channels have been sounded frequently since. A resurvey of the shoreline and wharves of New York Harbor was made in 1875.

Note. Re-survey of the Delaware River commenced in 1877
Triangulation in 1877 from Bridesburg to Chester, in 1880 to New Castle, in 1881 to Collin's Beach.
Topography in 1878 & 79 from Bridesburg to Fort Mifflin, in 1880 to Chester.
Hydrography in 1878 from Bridesburg to Fort Mifflin, in 1881 to Collin's Beach

UNITED STATES
COAST AND GEODETIC SURVEY

Sketch Showing the

TRIANGULATION AND GEOGRAPHICAL POSITIONS
IN

## SECTION No. II

From New York City to Cape Henlopen

Scale $\frac{1}{400,000}$

June 30 1881

——— Signifies Lines between primary occupied stations
——— do. do. do. secondary do. do.

Ch. do. Church
Ho. do. House
H. do. Hill
N. do. Neck

✱ Signifies Light House
♁ do. Cupola or Spire
♂ do. Signal

Note. One kilometer or 1000 meters = 3280.87 ft. = $\frac{5}{8}$ of a statute mile nearly. One statute mile = 1609.33 meters.

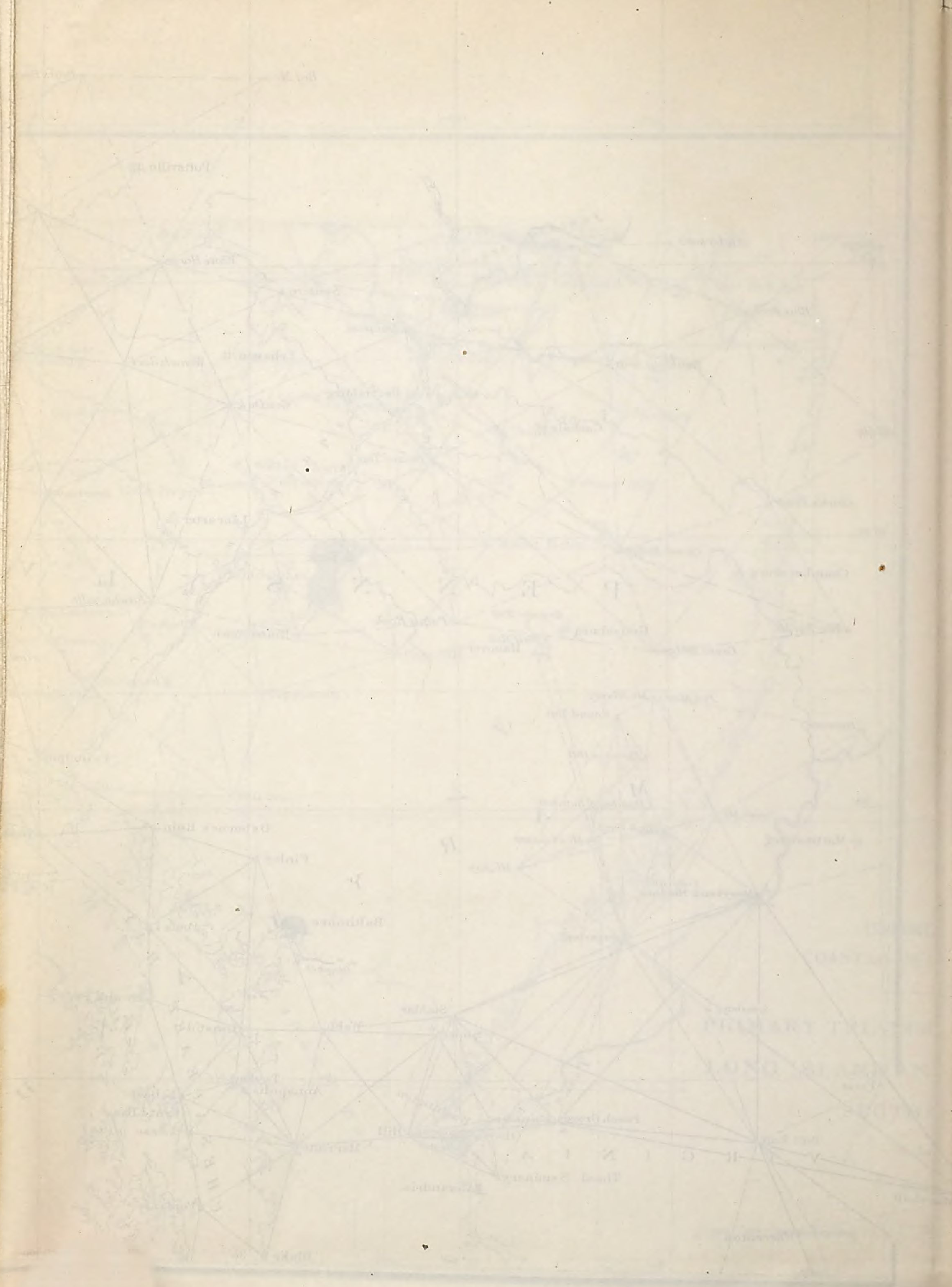
UNITED STATES
COAST AND GEODETIC SURVEY

## PRIMARY TRIANGULATION BETWEEN LONG ISLAND AND THE BLUE RIDGE

## SECTIONS II & III

Scale $\frac{1}{1,000,000}$

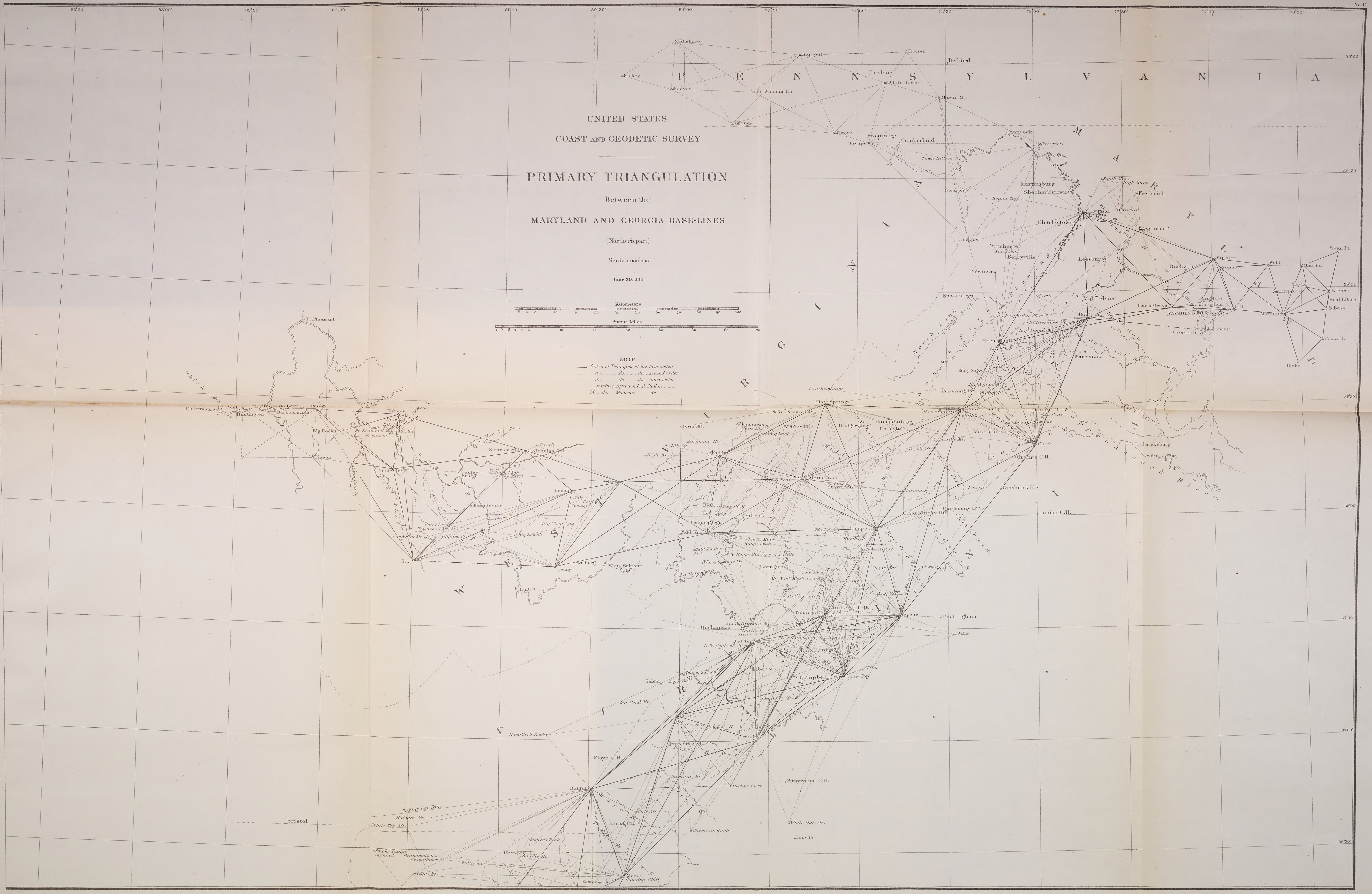
June 30, 1881


Pottsville
Lancaster
Baltimore
Annapolis

Meetinghouse H.

PLATE No. 1623

No. 10



UNITED STATES

COAST AND GEODETIC SURVEY

# PRIMARY TRIANGULATION

Between the

## MARYLAND AND GEORGIA BASE-LINES

(Northern part)

Scale $\frac{1}{1\,000\,000}$

June 30, 1881

NOTE

- Sides of Triangles of the first order
- do. do. do. second order
- do. do. do. third order

A. signifies Astronomical Station

M. do. Magnetic do.

PLATE No. 1370

(Southern part)

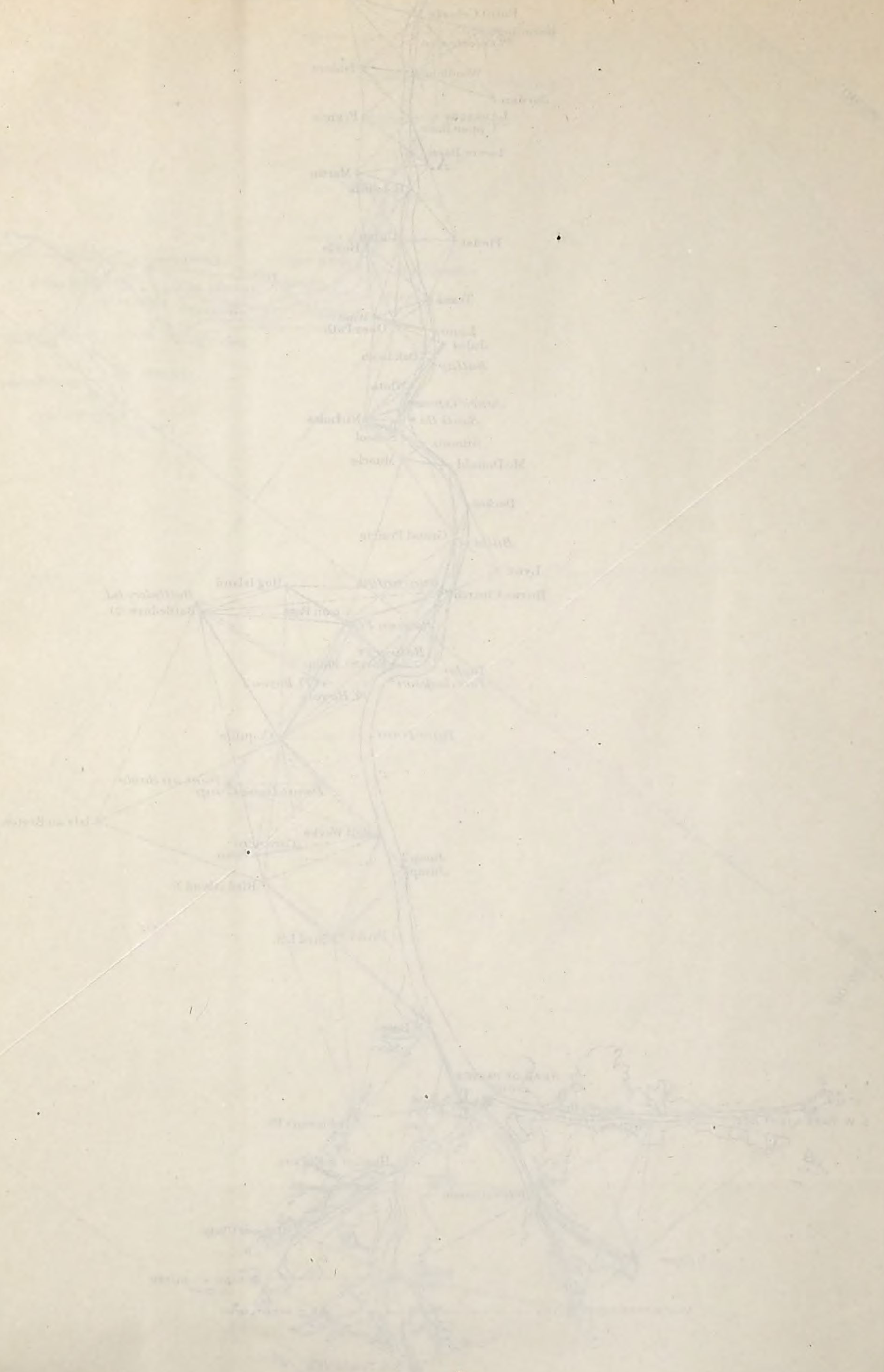
UNITED STATES
COAST AND GEODETIC SURVEY

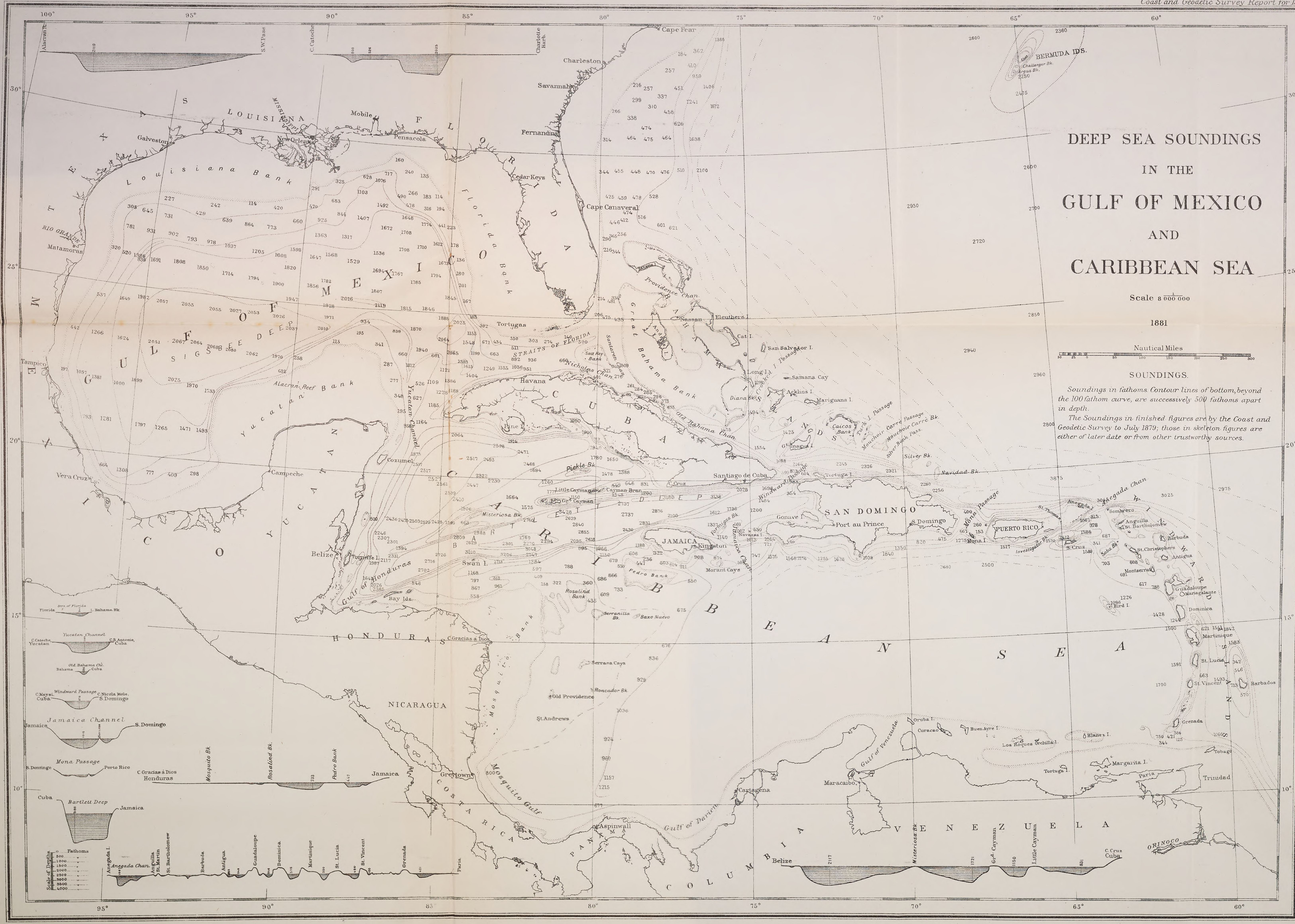
## PROGRESS SKETCH SEC. VI

EAST COAST OF FLORIDA
FROM AMELIA ISLAND TO HALIFAX RIVER
Scale $\frac{1}{200,000}$
June 30, 1881

NOTE
A. Signifies Astronomical Station
M.....do.....Magnetic..........do.....
——————......do.....Lines between Secondary occupied Stations
——— — — —......do.......do.......do...........do...........do......and unoccupied Stations
— — — — — —......do.......do.......do...........do.......unoccupied Stations
——————......do.......do.......do.....Tertiary occupied Stations
——— — — —......do.......do.......do.........do.........do......and unoccupied Stations
— — — — — —......do.......do.......do.........do.....unoccupied Stations
.. .. .. .. .. .. .......do.....Limits of Topographic Sheets
... ... ... ... ... .......do.......do.......Hydrographic Sheets
Vertical figures designate the number of Topographic Sheets
Inclined...do.........do...............do.........Hydrographic Sheets
The broken shore line is unsurveyed

**19**


Woodland
Martin
Hog Island
Grand Prairie
Levee
McDonald
Bayou Cove
Neck of Marsh



# DEEP SEA SOUNDINGS

# IN THE

# GULF OF MEXICO

# AND

# CARIBBEAN SEA

Scale $\frac{1}{8\,000\,000}$

1881

Nautical Miles

## SOUNDINGS.

*Soundings in fathoms. Contour lines of bottom, beyond the 100 fathom curve, are successively 500 fathoms apart in depth.*

*The Soundings in finished figures are by the Coast and Geodetic Survey to July 1879; those in skeleton figures are either of later date or from other trustworthy sources.*

U. S. COAST AND GEODETIC SURVEY

Carlile P. Patterson Supt.

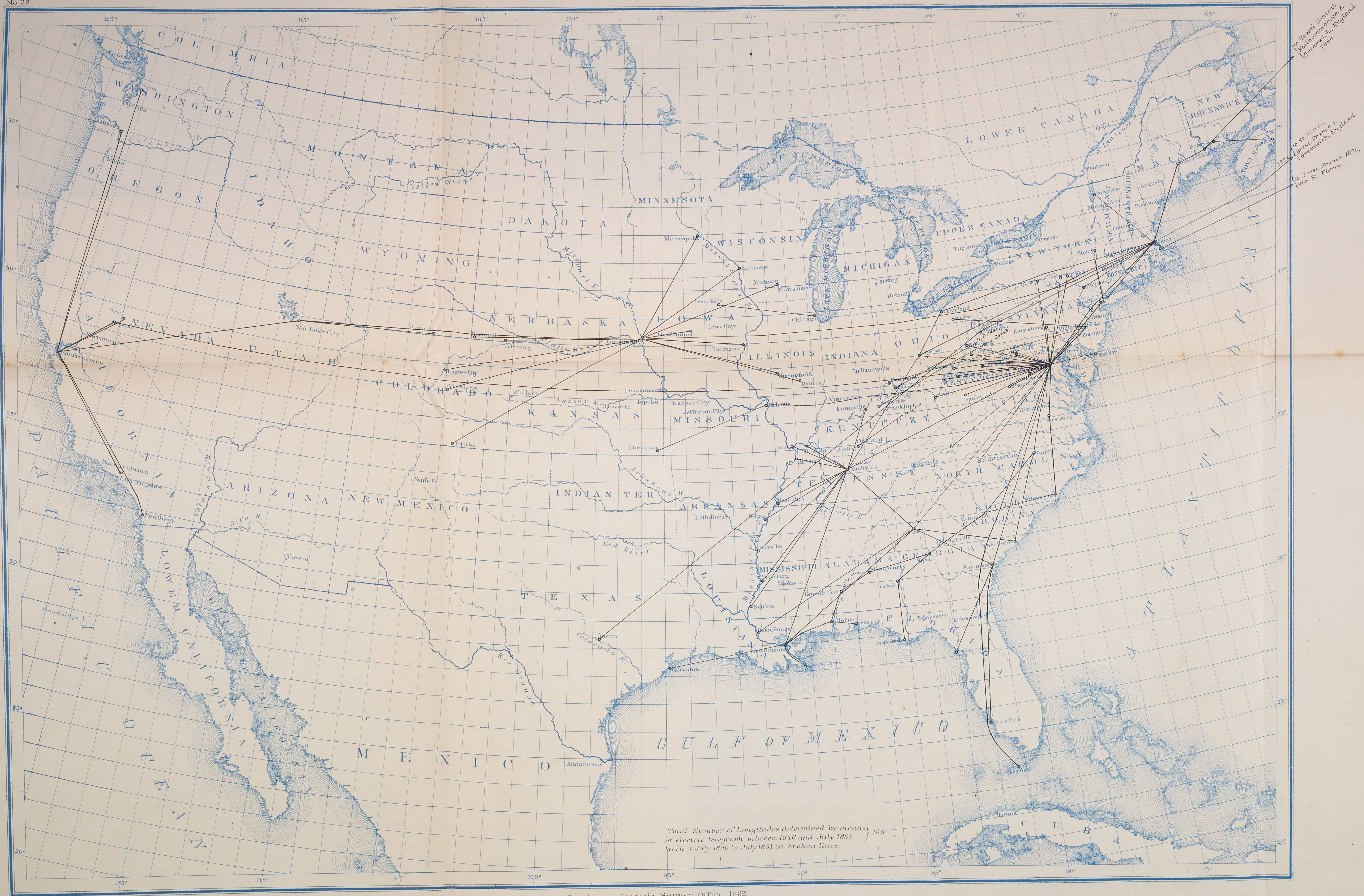
# CHART SHOWING LONGITUDE STATIONS AND CONNECTIONS

determined by means of the electric telegraph

between 1846 and July 1881

No 32

C & G S Report for 1881



Total Number of Longitudes determined by means of electric telegraph between 1846 and July 1881 } 105

Work of July 1880 to July 1881 in broken lines.

Drawn by A. Lindenkohl.

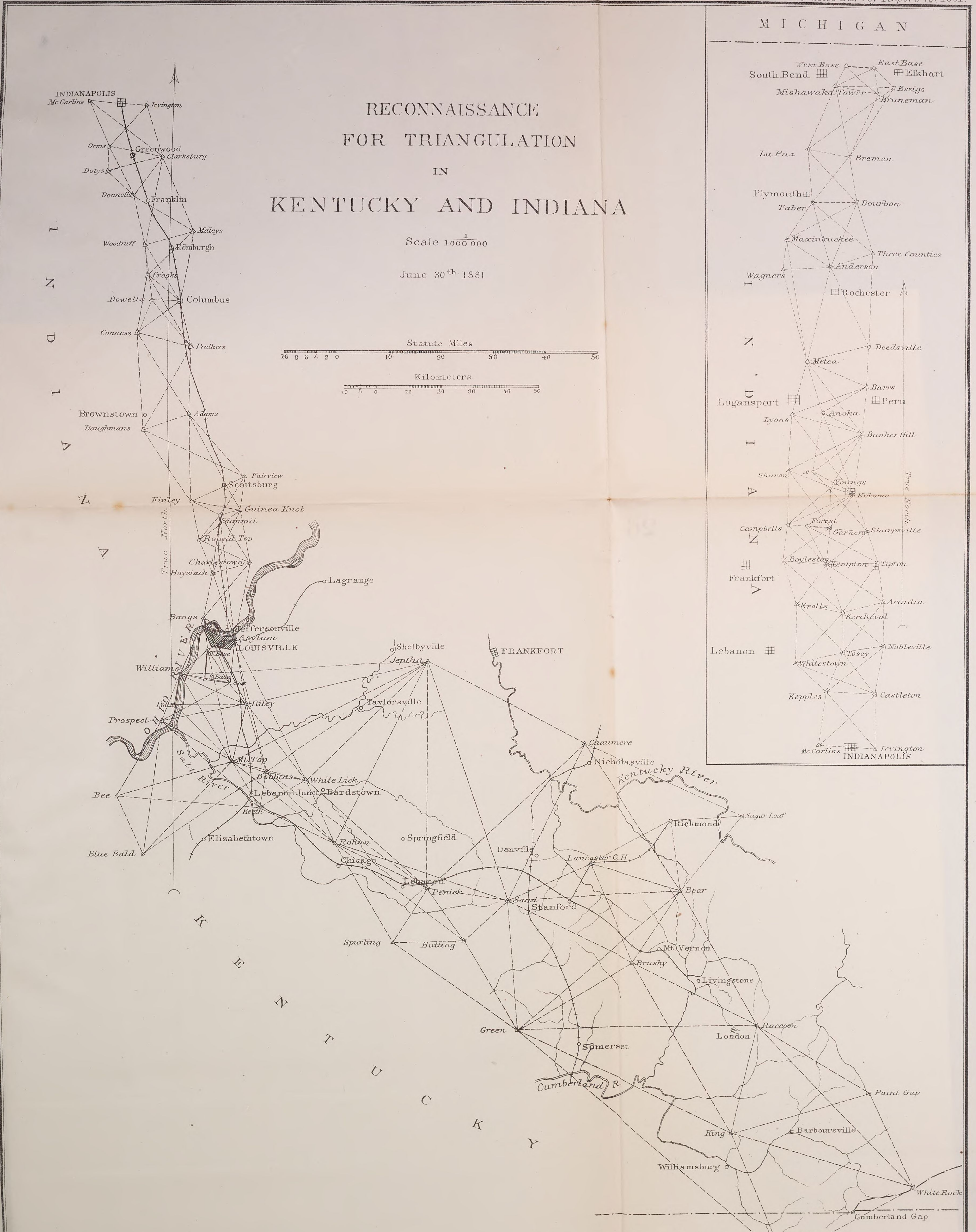
Coast and Geodetic Survey Office 1882.

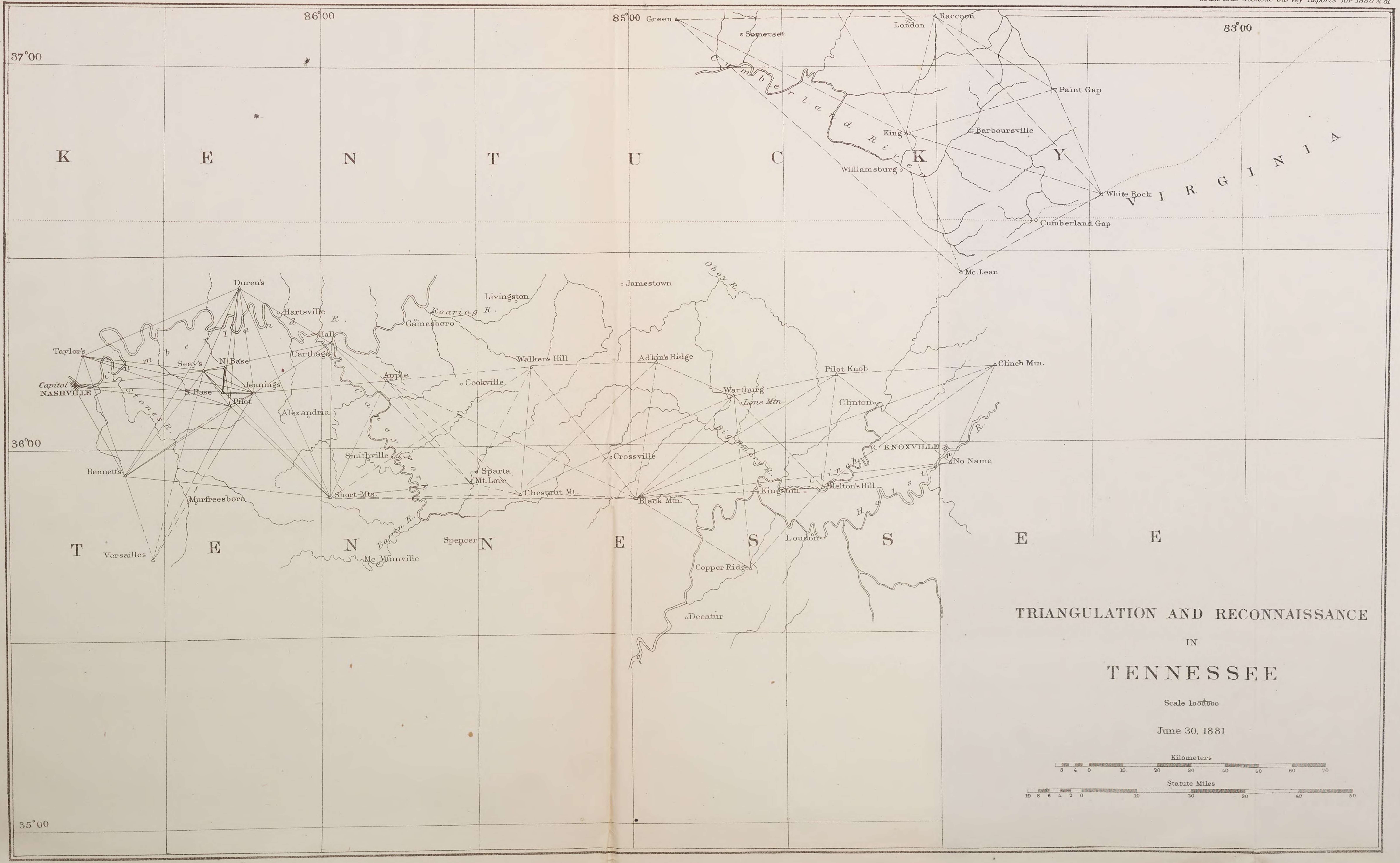
C. A. Schott, Assist.

# RECONNAISSANCE FOR TRIANGULATION IN KENTUCKY AND INDIANA

Scale $\frac{1}{1000\,000}$

June 30th 1881





# TRIANGULATION AND RECONNAISSANCE

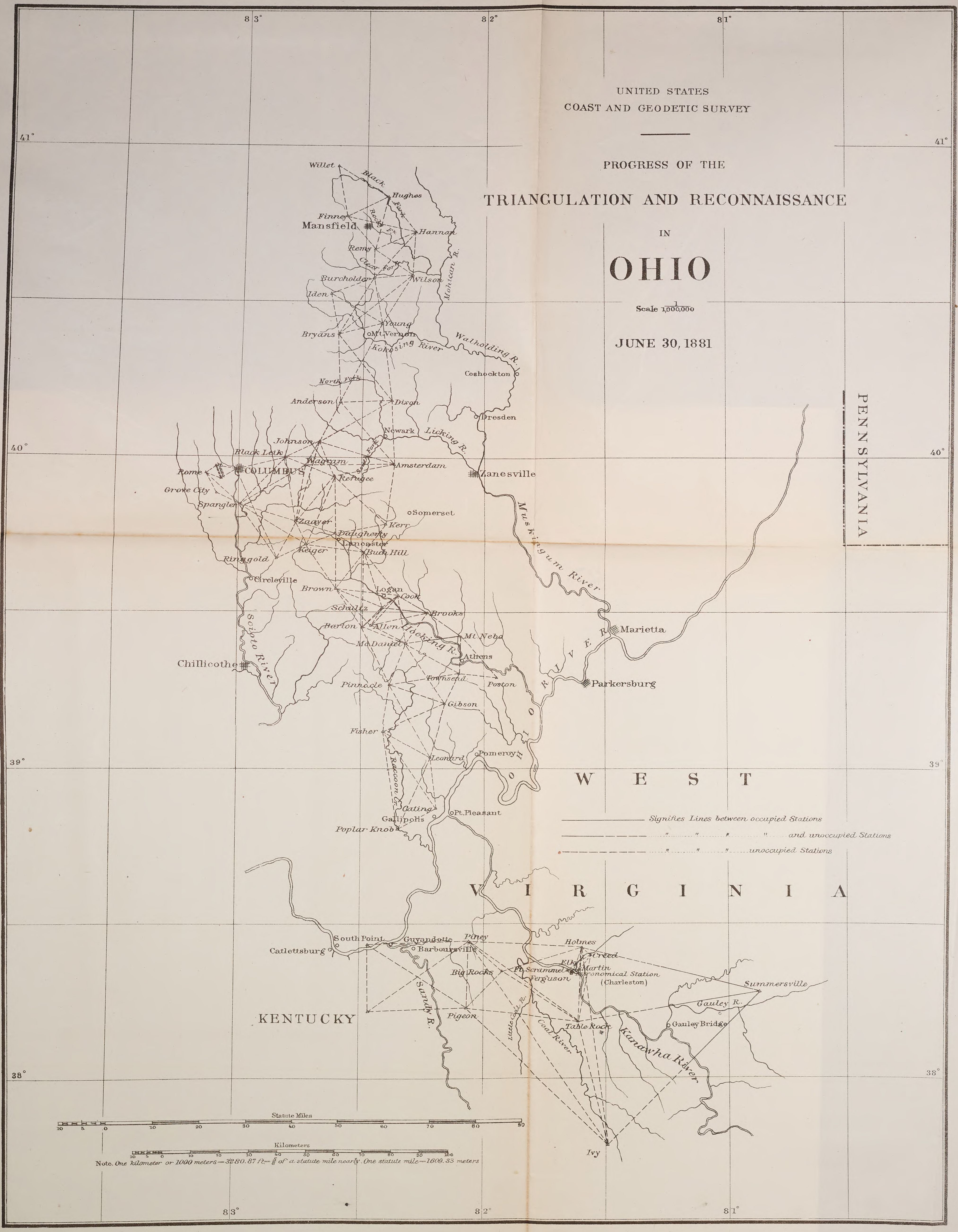
IN

# TENNESSEE

Scale $\frac{1}{1000000}$

June 30, 1881

No. 27a



UNITED STATES
COAST AND GEODETIC SURVEY

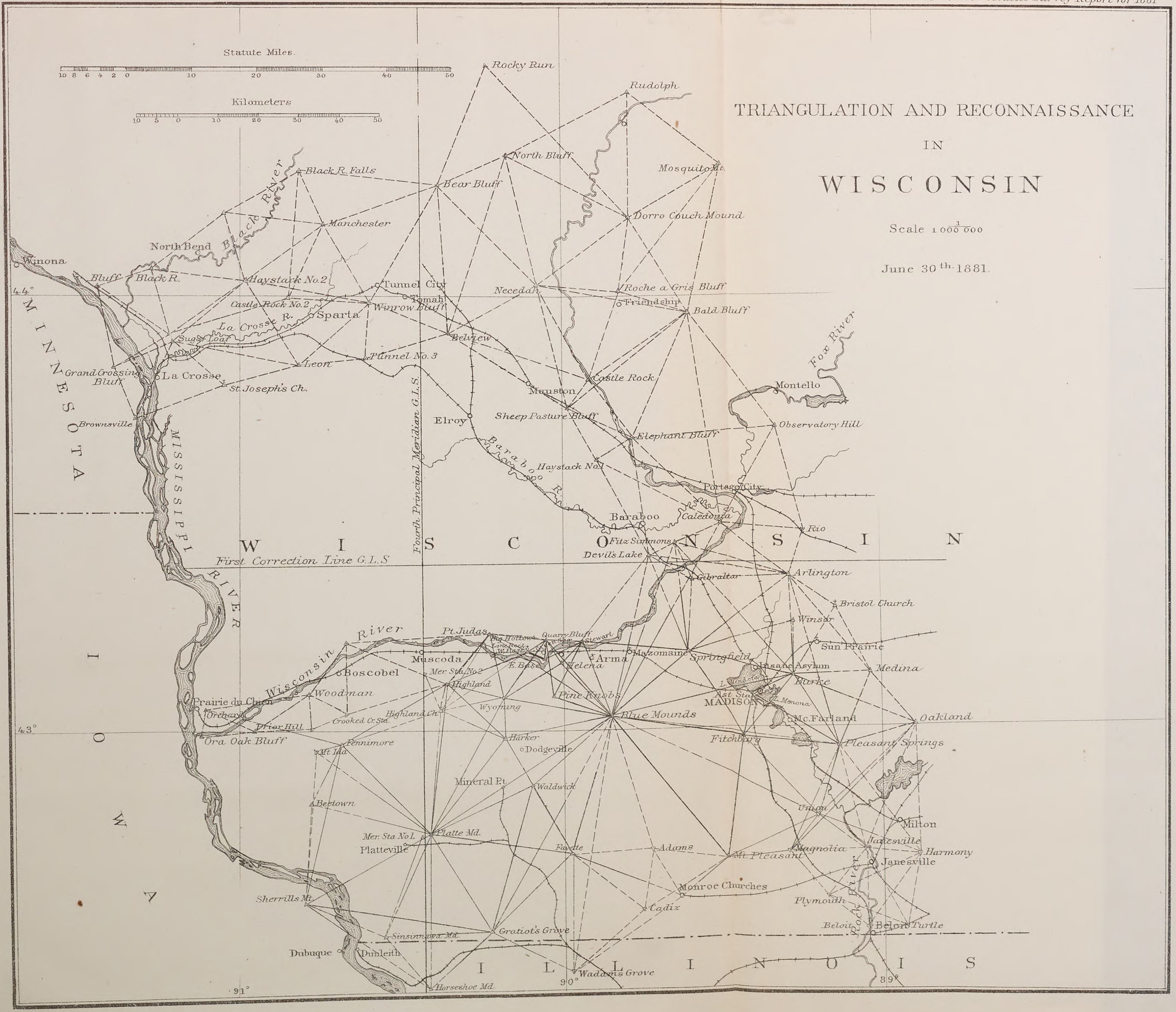
## PROGRESS OF THE
## TRIANGULATION AND RECONNAISSANCE
## IN
# OHIO

Scale $\frac{1}{1,000,000}$

JUNE 30, 1881

Signifies Lines between occupied Stations
" " " " and unoccupied Stations
" " " unoccupied Stations

Note. One kilometer or 1000 meters = 3280.87 ft. = $\frac{5}{8}$ of a statute mile nearly. One statute mile = 1609.33 meters



# TRIANGULATION AND RECONNAISSANCE
IN
# WISCONSIN

Scale $\frac{1}{1\,000\,000}$

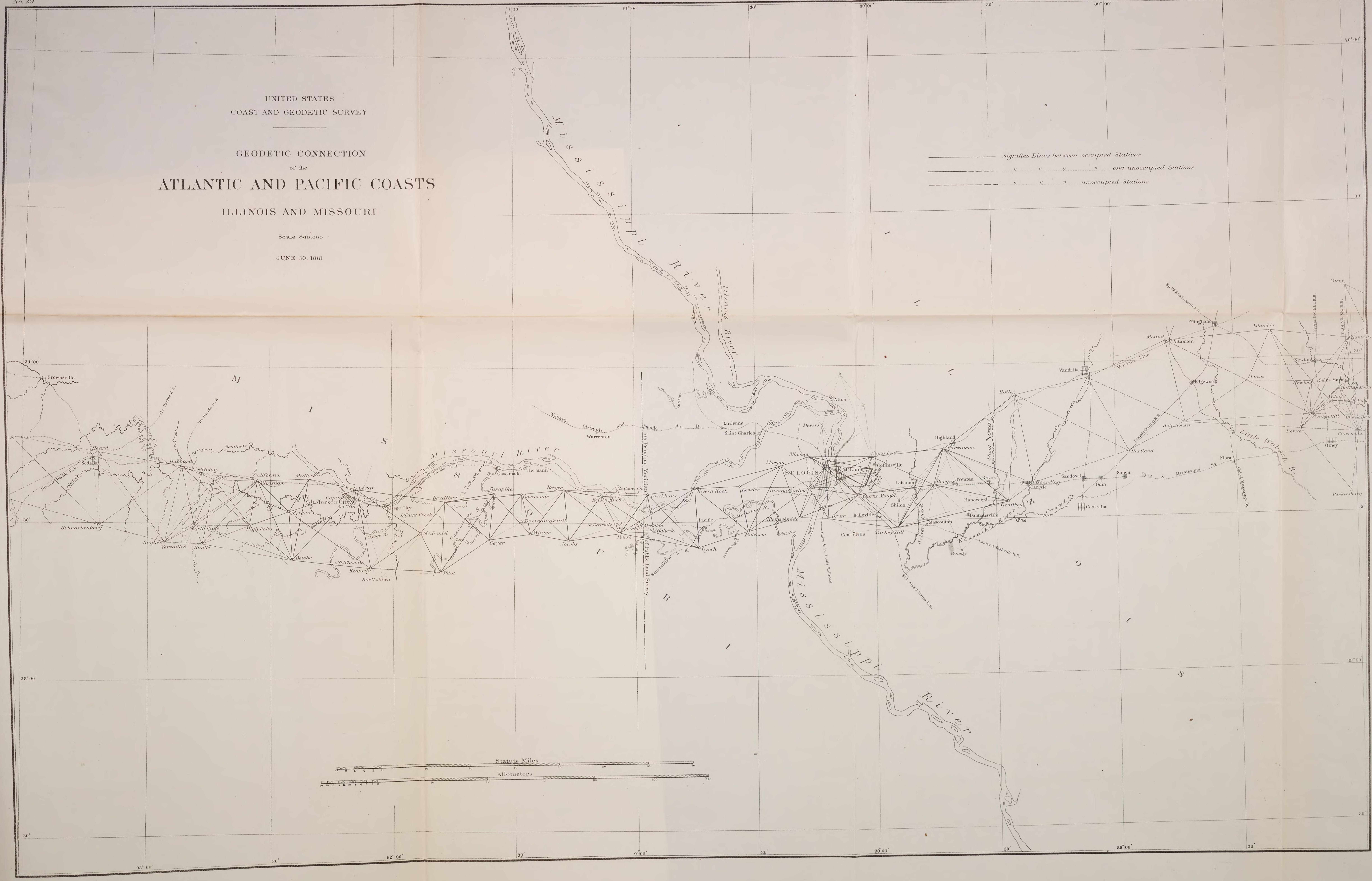
June 30th. 1881.

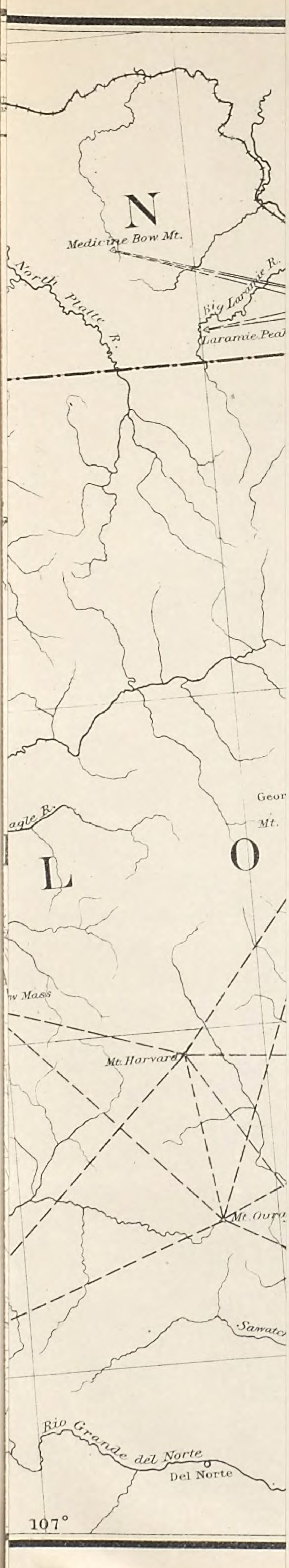
UNITED STATES
COAST AND GEODETIC SURVEY

# GEODETIC CONNECTION
of the
# ATLANTIC AND PACIFIC COASTS
## ILLINOIS AND MISSOURI

Scale $\frac{1}{800,000}$

JUNE 30, 1881




N
Medicine Bow Mt.
North Platte R.
Big Laramie R.
Laramie Peak
Geor
Mt.
agle R.
L
O
w Mass
Mt. Harvard
Mt. Oura
Sawatch
Rio Grande del Norte
Del Norte
107°

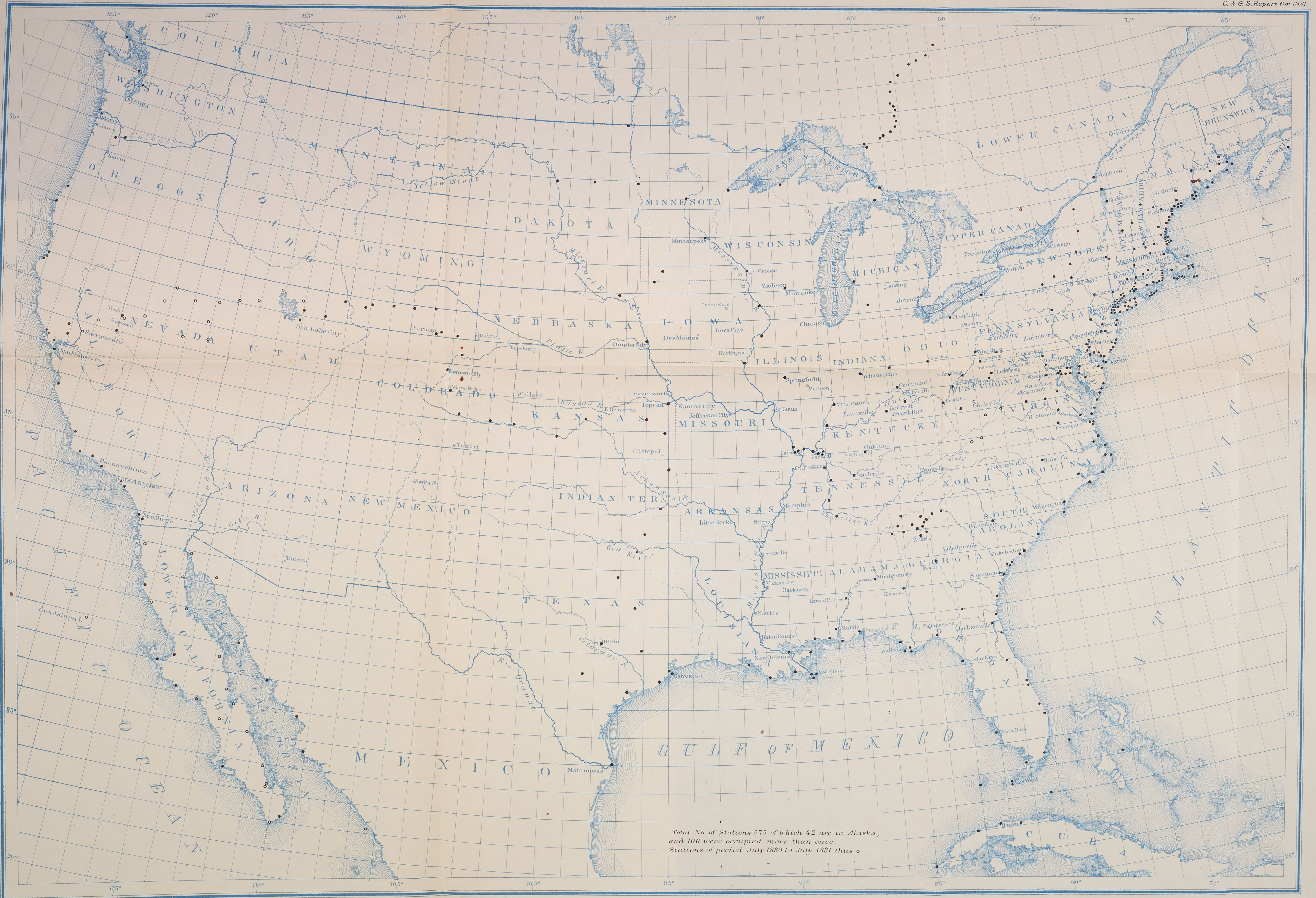
U. S. COAST AND GEODETIC SURVEY.
Carlile P. Patterson, Supt.

# CHART SHOWING POSITIONS OF MAGNETIC STATIONS

occupied between 1844 and July 1881.

No. 31

C. & G. S. Report for 1881.



Total No. of Stations 575 of which 42 are in Alaska;
and 100 were occupied more than once.
Stations of period July 1880 to July 1881 thus ○

Drawn by A. Lindenkohl.

Coast and Geodetic Survey Office 1882.
C.A. Schott, Assist.

## U. S. COAST AND GEODETIC SURVEY

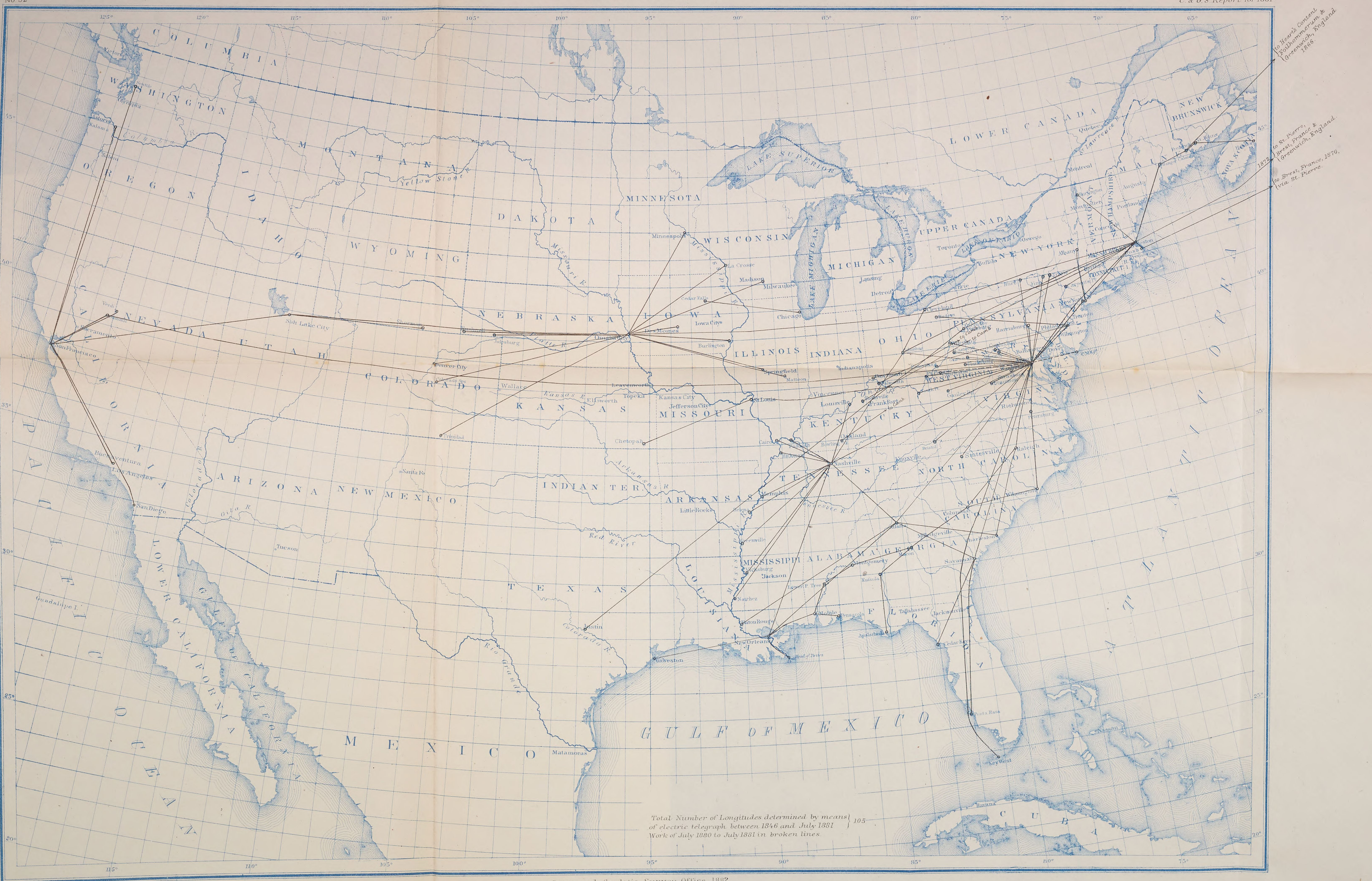
Carlile P. Patterson Supt.

# CHART SHOWING LONGITUDE STATIONS AND CONNECTIONS

determined by means of the electric telegraph
between 1846 and July 1881

No 32

C. & G. S. Report for 1881



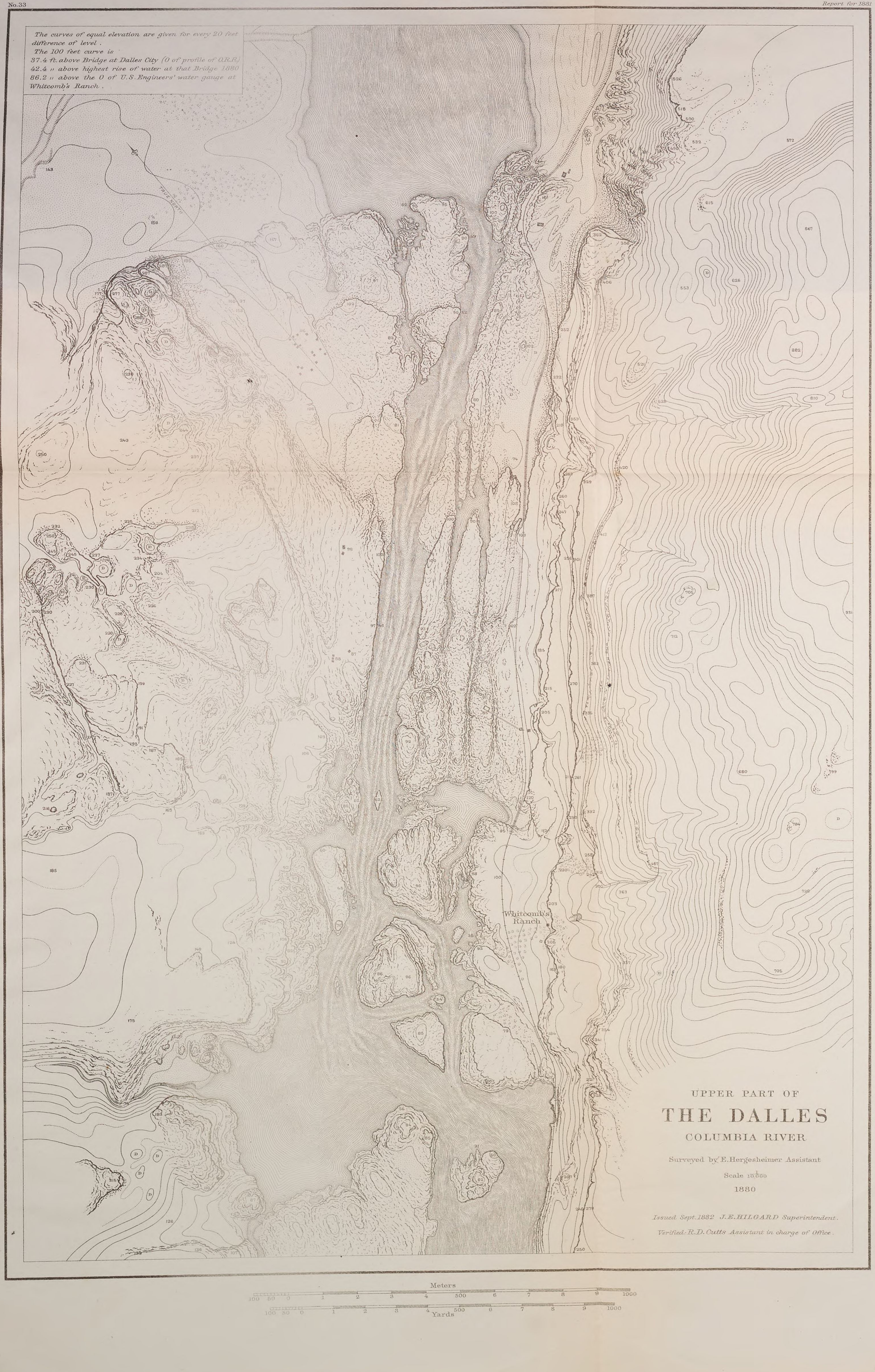
Total Number of Longitudes determined by means of electric telegraph between 1846 and July 1881 } 105
Work of July 1880 to July 1881 in broken lines.

Drawn by A. Lindenkohl.

Coast and Geodetic Survey Office 1882.
C. A. Schott, Assist.

U.S. COAST AND GEODETIC SURVEY

C.P. PATTERSON Superintendent



*The curves of equal elevation are given for every 20 feet difference of level.*

*The 100 feet curve is*

*37.4 ft. above Bridge at Dalles City (0 of profile of O.R.R.)*
*42.4 " above highest rise of water at that Bridge 1880*
*86.2 " above the 0 of U.S. Engineers' water gauge at Whitcomb's Ranch.*

UPPER PART OF

# THE DALLES

COLUMBIA RIVER

Surveyed by E. Hergesheimer Assistant

Scale $\frac{1}{10.000}$

1880

*Issued Sept. 1882 J.E. HILGARD Superintendent.*

*Verified: R.D. Cutts Assistant in charge of Office.*

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Senate documents

Bd.: [345.] 1881/82, Vol. 3 = Congress 47, Sess. 1

Washington, DC 1883

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urn:nbn:de:bvb:12-bsb11547857-7